The Investigation of Backdrafting at
200 Linacre Road in Winnipeg

May 1985

REPORT FOR

CANADA MORTGAGE AND HOUSING CORPORATION

THE INVESTIGATION OF BACKDRAFTING AT 200 LINACRE ROAD IN WINNIPEG

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FINAL REPORT

MAY 31, 1985

G.K. Yuill & Associates Ltd.
Consulting Engineers

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ABSTRACT

A study was performed to determine the cause of severe backdrafting problems in a Winnipeg house and remedial measures that could be taken. The project consisted of two phases. The first phase involved determining equivalent leakage areas of various exhausting equipment and inspection of the building envelope for leaks. The second phase involved the testing of a supply fan installed in the fresh air duct. This fan was controlled by the operation of various items in the house, including exhaust fans, clothes dryer, fireplace and furnace. In this test, the effect of the supply fan on the backdrafting caused by the exhaust fans, clothes dryer and fireplace was observed.

1.0 SUMMARY

An investigation of the backdrafting problems at 200 Linacre Road in Winnipeg was conducted to determine if the cause of the problem could be found and if a remedial measure could help solve the problem. Serious backdrafting occurred in this house in the winter of 1983-84 which resulted in a case of nonfatal carbon monoxide poisoning.

The project was broken down into two phases. The first phase dealt with trying to the locate the problem in the house by determining the flow of air in and out of the house.

The second phase dealt with developing a remedial measure. It involved installing a fan and heater unit in the fresh air supply of the house. This unit operates under conditions susceptible to backdrafting such as when the fireplace is operating.

The results of phase one were inconclusive. Appropriate leakage areas were found for the various items of equipment in the house. A search for leaks in the building envelope was conducted, but it did not reveal why this particular house was so susceptible to backdrafting and why the backdrafting remained so stable.

The results of phase two were more interesting. The fan and heater unit that was put into the fresh air supply duct did prevent backdrafting from occurring in all situations although it did not eliminate an existing backdraft in all situations. The key to this phase was the performance of the kitchen exhaust fan. Due to the large size of this fan, it was the major contributor to the backdrafting problem and as such, the major influence on the control stategy of the fan and heater unit. Although this was the case for this particular house, other houses may require different strategies. The universal remedial strategy for backdrafting would require more extensive study of different houses and house types.

2.0 INTRODUCTION

This document is the final report for a project entitled "The Investigation of Backdrafting at 200 Linacre Road in Winnipeg" presenting the results of extensive tests done on this house to determine its characteristics with regard to furnace backdrafting.

In December of 1983, this house had a case of carbon monoxide (CO) poisoning. The occupants woke one morning with headaches and a general ill feeling. One of the occupants passed out in the second floor hallway. They evacuated the house and called the fire department who discovered the backdraft. Doors and windows were opened and the house returned to normal. The temperature outside that night, as well as for several days previous, was very cold (below -30 °C). The fireplace had been running the night before as well as the clothes dryer. Also, the furnace flue pipe that night had been cold with water dripping off from condensation. The homeowners were unaware this was a sign of backdrafting.

Preliminary tests were performed on this house as part of a previous project. These tests involved evaluating a method of measuring backdraft potential which could be done by the homeowners. It consisted of shutting all building openings and progressively turning on exhausting devices in the home until a backdraft occurred, if at all. A candle flame was held against a small hole in the furnace flue to determine whether a backdraft occurred. The flame being blown away from the hole indicated a backdraft. The results of these tests indicated that this house was particularily susceptible to furnace backdrafts. In fact, a stable backdraft was induced even with a door slightly open. The present project was initiated to try to explain this performance and to develop remedial measures.

The tests were conducted in two parts. The objective of the first part was to determine whether this house had certain unique features which caused it to have such severe backdrafting problems.

This involved determining the equivalent leakage areas of various devices in the house using a blower door, and visually searching for leaks in the building envelope. The main purpose of the second part of the project was to test the performance of a duct heater/fan assembly installed in the fresh-air supply duct for the house. This unit was installed so that it would be activated at times of high backdraft potential, such as when a fireplace was burning or when an exhaust fan was running. Testing of this unit was carried out during backdrafting and/or potential backdrafting induced by a blower door. The blower door is described in Appendix A. Several different control strategies for the unit were evaluated.

3.0 PRELIMINARY TESTS OF THE HOUSE

3.1 Test Procedure

The initial phase of testing involved determining the air-tightness of the house, equivalent leakage areas (ELA's) of the various exhausting devices, and determining the location of possible leaks in the building envelope. This was done using a blower door. The ELA for each of the exhaust fans was calculated as was done for the dryer. The effect of the furnace fan was also tested in a similar fashion. To determine individual ELA, all other openings in the house had to be sealed off for the duration of the test. These openings included all doors and windows, the fresh air duct, exhaust fans, and the dryer vent. The fresh air duct was sealed by closing the damper. The exhaust fans, both kitchen and bathroom, were sealed with plastic and tape to make the openings airtight. These openings also included the fireplace and furnace chimneys which meant turning off the furnace and hot water heater pilots. The hot water heater flue joins into the furnace flue before reaching the chimney. A diagram of this setup is given in Appendix D.

During the depressurization tests, a visual examination of the house was performed in an attempt to locate leaks in the building envelope. This search was performed during depressurization so that any leaks that did exist, especially smaller ones, would appear more evident when a smoke pencil was used to find the drafts. The most likely areas where leaks should occur would be around window and door frames, joins between the foundation and building, and cracks in the building envelope.

3.2 Initial Test Results

The first phase of testing yielded the results for fan and dryer ELA. These results are displayed in Appendix B. The visual

locations of leaks. In fact, this particular house is very well and very evenly sealed. If significant leaks were found, then the position of the neutral pressure plane could have been found and its relationship with the backdrafting problem could be evaluated. This was not possible within the scope of the project budget.

4.0 TEST OF CONTROLLED AIR SUPPLY FAN

4.1 Introduction

Backdrafting is most likely to occur during periods of low pressure in the house. These conditions arise when the exhaust fans or dryer are running or when the fireplace is operating. A furnace fan may also cause a net outflow from the house. The most logical way to avoid backdrafting is to eliminate the pressure drop. Supplying air to the house at the the same time that these devices are removing it should maintain conditions that are not susceptible to backdrafting.

The method which was developed to eliminate the low pressures in the house uses an axial flow fan mounted in the fresh-air supply duct. A proportionally controlled 5 kW heater was mounted downstream of the fan to warm the incoming air up to room temperature. It prevented the outside air from causing cold drafts in the house when the unit was operating. The duct heater/fan assembly is activated either manually (when using the fireplace) or automatically (when the kitchen exhaust fan or dryer is turned on). A detailed description is given in Appendix C.

The fan/heater unit was installed into the existing 15 cm fresh-air duct that feeds into the return air plenum of the gas furnace. It was situated approximately one meter upstream from the plenum. This location was used because it had the easiest access and caused the least amount of obstruction in an already cramped area of the basement. The location was quite suitable from a performance standpoint as well. The temperature sensor was mounted approximately 80 cm downstream of the heater. At this point, it could read a well mixed stream of air and thus give proper temperature control to the heater. The fan was mounted 30 cm upstream of the heater and had a nominal flow rate of 110 l/s.

The control stategy was such as to activate the fan/heater unit when air was exhausted from the house. There were four sensing points in the layout. A current transformer was installed on the dryer power supply to sense when the dryer was turned on. Relays were connected to the kitchen exhaust fan switch and the furnace thermostat respectively to indicate when each of these was activated. Also, a manual switch was located near the fireplace so that it could be turned on when a fire was burning in the fireplace. All of these controls had switches installed to make it possible to disable them for different tests, so that the impact of each of the controls on the reduction of backdrafting could be investigated.

4.2 Test Procedure

The objectives of these tests were to test the effectiveness of the duct heater/fan assembly on the prevention and alleviation of backdrafts and to find which control stategy for the unit was the most effective. This was achieved by testing all combinations of conditions that were potentially hazardous for backdrafting which could occur in the house.

A blower door was used to create an outflow from the house to induce a backdraft in the furnace. This blower door had a variable speed fan and a calibrated nozzle which was used to measure how much air was being exhausted from the house. It included a manometer to find the pressure difference across the house. Another inclined manometer was used to measure the static pressure in the chimney. This indicated exactly when a backdraft was occurring and how strong it was. A description of the test equipment is given in Appendix A.

The tests were divided into three different categories. The first series was performed without the duct heater/fan unit operational. This made it possible to see the effect of the unit compared to existing conditions. The second series dealt with backdraft conditions that occurred while the duct heater/fan unit was

operational. These tests showed the effectiveness of the unit in preventing backdrafts. The third series dealt with backdraft conditions that occurred before the unit was operational. These tests showed the effectiveness of the unit on the elimination of existing backdrafts.

The tests were as follows:

WITHOUT THE DUCT HEATER/FAN UNIT OPERATIONAL

Test No.	
1	House as is, nothing operating
2	Fireplace operating
3	Fireplace, kitchen exhaust fan operating
4	Fireplace, dryer operating
5	Fireplace, furnace operating
6	Fireplace, furnace, kitchen exhaust fan operating
7	Fireplace, furnace, kitchen exhaust fan, dryer operating
8	Kitchen exhaust fan operating
9	Furnace operating
10	Furnace, kitchen exhaust fan operating
11	Furnace, kitchen exhaust fan, dryer operating

WITH THE DUCT HEATER/FAN UNIT OPERATIONAL AND NO INITIAL BACKDRAFT

Test No.	
12	Fireplace operating
13	Fireplace, kitchen exhaust fan operating
14	Fireplace, kitchen exhaust fan, dryer operating
15	Fireplace, furnace operating

16	Fireplace, furnace, kitchen exhaust fan operating
18	Fireplace, furnace, kitchen exhaust fan, dryer operating
19	Kitchen exhaust fan operating
20	Kitchen exhaust fan, dryer operating
21	Furnace, kitchen exhaust fan,
22	Kitchen exhaust fan, furnace operating
24	Furnace, dryer operating

(Tests Nos. 17 and 23 are intentionally omitted.)

WITH THE DUCT HEATER/FAN UNIT OPERATIONAL
AND AN INITIAL BACKDRAFT

Test No.	
25	Fireplace operating
26	Fireplace, kitchen exhaust fan operating
28	Fireplace, kitchen exhaust fan, dryer operating
29	Fireplace, furnace operating
31	Fireplace, furnace, kitchen exhaust fan operating
33	Fireplace, furnace, kitchen exhaust fan, dryer operating
34	Kitchen exhaust fan operating
35	Kitchen exhaust fan, dryer operating
37	Furnace, kitchen exhaust fan operating
38	Furnace, kitchen exhaust fan, dryer operating
40	Furnace, dryer operating
41	Furnace operating

(Test Nos. 27, 30, 32, 36 and 39 are intentionally omitted.)

In these tests, an actual woodburning fire was not used in the fireplace. Instead, a propane burner was placed in the fireplace and operated at full heat. This set up allowed for more control over the intensity and duration of the fire. The propane burner gave a constant flame and could be turned off when desired. The effects of a fluctuating fire were eliminated. As well, the operation was much cleaner than an actual fire.

The results from these tests are shown in Appendix B.

4.3 Results of Tests

All of the field data, tables and graphs can be found in Appendix B. Since the original inspection of this house done on a previous project, a fresh air supply duct had been installed. As such, the susceptibility of the house to backdrafting was less. This is a relatively subjective observation because the original tests did not involve quantitative measurements of backdrafting conditions. Still, the house was quite susceptible to backdrafts even with the new duct. The use of the duct heater/fan unit appeared to have a net postive effect on alleviating this problem. The total number of situations in which backdrafting occurred went down with the use of the duct heater/fan unit. Yet, situations did occur where the unit could not overcome the backdraft. As long as the furnace was not already backdrafting, the unit effectively prevented a backdraft from occurring.

When backdrafts already existed, there were five cases tested where the duct heater/fan assembly would not eliminate the backdraft. These were when the:

a) furnace and kitchen exhaust fan,
b) furnace, kitchen exhaust fan and dryer,
c) furnace, kitchen exhaust fan, dryer and fireplace,
d) fireplace, and kitchen exhaust fan or,
e) kitchen exhaust fan only

were operating. Clearly the kitchen exhaust fan was operating in all of these cases. In fact, just the fireplace and kitchen exhaust fan operating simultaneously created a backdraft as long as the duct heater/fan unit was not operating. This situation indicated that the kitchen exhaust fan was the major contributor to the backdrafting problem in this house.

The dryer had the least effect on backdrafting. It did not have a major effect on any of the cases tested.

The furnace was able to avoid backdrafting as long as one did not already exist upon start up. The cases where the furnace could not reverse an existing backdraft were also cases where the kitchen exhaust fan was running as well. The dominant factor here again was the operation of the kitchen exhaust fan and not the operation of the furnace. The pressure difference across the house required to create a backdraft dropped as other components were subsequently operation. At no point though, would a situation occur where the duct heater/fan unit could not prevent a backdraft.

An interesting phenomenon occurred during tests with the furnace running. The pressure difference across the house that was required to produce a backdraft when the duct heater/fan unit was operating was actually less than the pressure difference required when the unit was not running. This appeared to be the opposite of what would be expected. However, the reason for this was apparent. The blower door and associated gauges were located on the main floor and the fresh air inlet and gauge to read the flue pressure (to test for a backdraft) were located in the basement. In this situation, there could have been a pressure difference between the two areas during the testing. This could have happened because of the location of ductwork in the basement. Cold air was fed into the furnace via the return air plenum. A supply register was located directly beside the furnace. The combination of these two caused the incoming air to be essentially dumped directly into the basement beside the furnace. In this instance,

the pressure directly around the furnace was higher than that of the rest of the house even though the gauge upstairs did not show this. This situation is desireable because this pressure difference aids againsts backdrafting.

4.4 Conclusions

On the whole, the duct heater/fan unit helped prevent the occurrance of backdrafts but in some situations, did not manage to alleviate existing backdrafts. The unit would need a larger capacity fan to meet all requirements. The size of this fan has not been estimated.

As for the control strategy, the dryer connection was deemed unnecessary because of the minor effect of the dryer. The furnace connection was also not necessary because of its ability to overcome backdrafts as is. The kitchen exhaust fan connection is essential due to the severe problems that this component creates. The fireplace switch was also necessary for preventing backdrafting. It supplied additional fresh air for the fireplace operation as well.

A condition where the kitchen exhaust fan and fireplace were operating together was potentially a backdrafting problem in itself. One solution to this could have the fireplace and kitchen fan switch connected so that neither could be on at the same time. The fireplace switch would override the kitchen exhaust fan, turning it off, and operate the duct heater/fan unit.

The possibility was considered of not having the duct heater/fan unit operating when the furnace was not operating. Why try to prevent a backdraft in the furnace flue when the furnace isn't even operating? The reasons were twofold. Upon start up of the furnace, an increase in the spillage of combustion products out of the dilution hood could occur if the duct heater/fan is not operating. Also, the

hot water heater requires an adequate updraft to prevent it from backdrafting as well.

The configuration of the duct heater/fan unit necessary to adequately prevent backdrafts from occurring consisted of the duct heater/fan unit as it was with the kitchen exhaust fan and fireplace controlling the operation. The kitchen exhaust fan switch and the fireplace switch should also be connected so that the kitchen exhaust fan could not operate at the same time as the fireplace. If the results had shown that the unit need be operated only during times when the furnace was running, then the duct heater would not have been necessary as the incoming air would be heated by the furnace. However, this strategy was not possible because of the greater difficulty of overcoming an existing backdraft because of the extra controls required, and because of the updraft required for the pilot light. With the recommended strategy, the control circuitry can be rather simple consisting of only a relay and a switch.

The control system which was in effect in the apparatus left in the house at the end of this test turned the heater/fan on when any of the components tested were operated. This was done to increase the fresh air supply of the house. Previously, it was rather low for a house of this size.

APPENDIX A

DESCRIPTION OF TEST EQUIPMENT

Blower door

The blower door consists of an axial flow fan mounted in a doorway exhausting air out of the house through a calibrated nozzle. The whole unit is mounted on a wood frame that fits snuggly into a doorframe thus not allowing any air flow through the doorway itself. Two manometers measure the house pressure and the nozzle pressure respectively. The house pressure gives the difference in pressure between the inside and the outside of the house. The nozzle pressure gives the static pressure in the nozzle and with the use of the calibration equation for the nozzle, the flowrate through the nozzle can be calculated. The axial flow fan is connected through a rheostat to allow the fan to be adjusted to any speed. To ensure that the effects of wind are negated as well as possible, the outside section of the house pressure manometer is split into four sections and pressures are read on all four sides of the house and integrated. This involves splitting the tube that runs from the outside end of the manometer into four tubes and attaching each one of the tubes to each one of the outside walls.

Flue manometer

The flue manometer consists of an inclined manometer measuring the pressure in the flue to determine if backdrafting is occurring. A pressure probe is mounted approximately 0.5 meter up from the base of the vertical run of the flue and connected to the manometer. The manometer itself is mounted in the basement and pressures are taken relative to the basement pressure. A negative pressure indicates if an updraft is occurring and consequently a positive pressure indicates the presence of a backdraft.

APPENDIX B

TABLES AND GRAPHS OF RESULTS

The results of phase one are shown in Tables B1.1 to B1.7. The ELA of the house was calculated to be 780 sq.cm. at 10 Pa. This gives an air change rate of 0.316 air changes per hour. This air change rate was obtained by using an hour by hour simulation of natural infiltration in Winnipeg. It should not be confused with air change rates measured at certain pressures using a blower door. This number confirms the air tight nature of this house. The exhaust fan, which was found to be the major contributor to the backdrafting problems calculated as having a flow rate of 70 l/s.

The results of phase two are shown in Tables B2.1 to B2.34 and Figures B2.1 to B2.9. The first series of tests (Nos. 1 to 11) test the house without the duct heater/fan unit operational. The second series of tests (Nos. 12 to 24) tested the house with the duct heater/fan unit operational and with no initial backdraft. The third series of tests (Nos 25. to 41) tested the house with the duct heater/fan unit operational but with an initial backdraft. The dashed lines on the graphs indicate the transition between updraft and backdraft conditions. Please note that tests 17, 23, 27, 30, 32, 36, and 39 are intentionally omitted as these were found to be redundant upon testing.

Certain abbreviations are used on the tables that follow. They are:

HP - difference in pressure between the inside and outside of house. The units are Pascals [Pa].

corrected HP - the HP adjusted so that the pressure difference when the blower door is not operating (usually the first reading) is zero.

NP - static pressure in the blower nozzle. It is used to

calculate the flow rate through the nozzle (see Q below). The units are kiloPascals [kPa].

corrected NP - the NP adjust so that the nozzle pressure is zero when the blower door is not operating. The units are kiloPascals [kPa].

Q - flow rate through the blower door measures in litres/second. It is calculated directly from the corrected nozzle pressure using the equation:

$$Q = c(\Delta P)^n$$

where Q = flow rate in l/s

c = 14.695

n = .49754

ΔP = corrected nozzle pressure in Pascals.

FP - pressure difference between furnace flue and basement. The units are Pascals [Pa] and a positive value indicates the presence of a backdraft.

TEST No 1 DATE 84/09/10 TIME 7:40

Phase One

CONDITIONS House AS IS

HP	NP	CORRECTED HP	CORRECTED NP	Q	COMMENTS
6	.05	.5	0	0	
17	.24	11.5	.19	200	
24	.42	18.5	.37	279	
32	.64	26.5	.59	351	
42	.99	36.5	.94	443	
50	1.27	44.5	1.22	504	
51	1.28	45.5	1.23	506	
60	1.61	54.5	1.56	570	
71	2.07	65.5	2.02	648	
61	1.61	55.5	1.56	570	
50	1.26	44.5	1.21	502	
41	.99	35.5	.94	443	
28	.55	22.5	.50	324	
18	.27	12.5	.22	215	
11	.13	5.5	.08	130	
5	.05	-0.5	0	0	

OBSERVATIONS n= .6565
C= 41.46
r= .9991

11 C
101.37 kPa

TABLE B1.1

TEST No 2 DATE 84/09/10 TIME 7:55

Phase One

CONDITIONS HOUSE SEALED

HP	NP	CORRECTED HP	CORRECTED NP	Q	COMMENTS
12.5	.130	1.5	0.02	165	
21	.280	10	0.17	242	
31	.470	20	0.36	314	
41	.700	30	0.59	382	
54	1.010	43	0.90	459	
37	.600	26	0.49	354	
26	.380	15	0.27	282	
17	.210	6	0.10	210	
11	.110	0	0	152	

OBSERVATIONS $n = .6871$
$C = 29.696$
$r = .9997$

11 C
101.37 kPa

TABLE B1.2

TEST No 3 DATE 84/09/10 TIME 8:10

Phase One

CONDITIONS BATH ROOM FAN RUNNING

HP	NP	CORRECTED HP	CORRECTED NP	Q	COMMENTS
6.5	.05	0	0	0	
18	.19	11.5	.14	172	
23	.34	16.5	.29	247	
30	.53	22.5	.48	317	
38	.78	31.5	.73	391	
47	1.02	40.5	.97	450	
54	1.28	47.5	1.23	506	
58	1.40	51.5	1.35	530	
52	1.18	45.5	1.13	486	
44	.90	375	.85	421	
12	.10	5.5	.05	103	

OBSERVATIONS n = .6925
C = 34.8215
r = .9956

9.5 C
101.401 kPa

TABLE B1.3

TEST No 4 DATE 84/09/10 TIME 8:30

Phase One

CONDITIONS BATHROOM & KITCHEN FAN RUNNING

HP	NP	CORRECTED HP	CORRECTED NP	Q	COMMENTS
11	.05	0	0	0	
21	.10	10	.05	103	
27	.20	16	.15	178	
36	.38	25	.33	263	
43	.56	32	.51	327	
52	.835	41	.785	405	
62	1.18	51	1.13	486	
51	.79	40	.74	393	
30	.28	19	.23	220	
17	.065	6	.015	57	
11	.05	0	0	0	

OBSERVATIONS n = .8802
C = 15.3816
r = .9962

9.5 C
101.401 kPa

TABLE B1.4

TEST No 5 DATE 84/09/10 TIME 8:45

Phase One

CONDITIONS BOTH FANS AND DRYER ON

HP	NP	CORRECTED HP	CORRECTED NP	Q	COMMENTS
14	.05	0	0	0	
23	.115	9	.065	117	
31	.24	17	.19	200	
44	.51	30	.46	310	
58	.92	44	.87	426	
52	.725	38	.675	376	
36.5	.32	22.5	.27	238	
22	.11	6	.06	113	

OBSERVATIONS n = .7551
c = 24.0278
r = .9929

9.5 C
101.401 kPa

TABLE B1.5

TEST No 6 DATE 85/09/10 TIME 9:10

Phase One

CONDITIONS ALL FANS - FRESH AIR INLET DAMPER CLOSED

HP	NP	CORRECTED HP	CORRECTED NP	Q	COMMENTS
15	.04	0	0	0	
26	.125	11	.085	134	
36	.27	21	.23	220	
48	.50	33	.46	310	
61	.83	46	.79	406	
51	.58	36	.54	336	
39	.325	25	.285	245	
24	.105	10	.065	117	

OBSERVATIONS n = .7962

c = 19.2505

r = .9993

9 C

101.48 lcfm

TABLE B1.6

TEST No 7 DATE 84/09/10 TIME 9:30

Phase One

CONDITIONS ALL FANS ON, FRESH AIR INLET DAMPER OPEN, FURNACE FAN ON

HP	NP	CORRECTED HP	CORRECTED NP	Q	COMMENTS
12.5	.045	0	0	0	
22	.115	9.5	.07	122	
32	.265	19.5	.22	215	
42	.500	29.5	.455	309	
52	.765	39.5	.72	388	
59	.99	46.5	.945	444	
43	.53	30.5	.485	319	
28	.20	15.5	.155	181	

OBSERVATIONS n = .8168

C = 19.3343

r = .9997

9 C

101.48 kPa

TABLE B1.7

COMPARISON OF EQUIVALENT LEAKAGE AREAS

Test No.	Description	ELA (cm^2)
1	House As Is	780
2	House Sealed	603
3	Fresh Air Inlet Open Bathroom fan Operating	1,061
4	Bathroom and Kitchen Exhaust Fan Operating	722
5	Both Fans and Dryer Operating	845
6	Fresh Air Inlet Closed All Fans and Dryer Operating	744
7	Same as 5 with Furnace Fan Operating Also	784

TABLE B1.8

Calculation of ELA and Air Change Rate

The ELA is calculated (at 10 Pa) using:

$ELA = 1.157 \times 10^{-3} \sqrt{\rho}\ c10^{n-0.5}$

where ρ is the density of air in the house

c, n are flow coefficients found using the blower door.

For $\rho = 1.3\ kg/m^3$, $c = 41.46$ and $n = .6565$:

$ELA = 1.157 \times 10^{-3} \sqrt{1.3} \times 41.46 \times 10^{0.6565-0.5}$

$= 0.78m^2\ (780\ cm^2)$

For Air Change Rate, must calculate N_o:

$$N_o = \frac{Lr_o \sqrt{P_s/P_{so}}\ t}{V}$$

where L is equivalent leakage area

r_o is a normalising constant equal to 0.75 m/s

$\sqrt{P_s/P_{so}}$ is equal to 1

t is the time period of interest (in this case 1 hour)

V is the house volume

Therefore:

$$N_o = \frac{0.78m^2 \times 0.75\ m/s \times 1 \times 3600\ s}{640\ m^3}$$

$= .329$

From the graph of $\overline{N_g}$ vs N_o, $\overline{N_g} = 1.04$

but $\overline{N_g} = \frac{c}{s} Lr_o \sqrt{P_s/P_{sw}}$

Solving for $\frac{s}{c}$

$$\frac{s}{c} = \frac{Lr_o \sqrt{P_s/P_{sw}}}{N_g}$$

$$= \frac{0.078\ m2 \times 0.75\ m/s \times 1}{1.04} \times \frac{ac}{640m^3} \times \frac{3600s}{hr}$$

$$= .316\ ac/hr$$

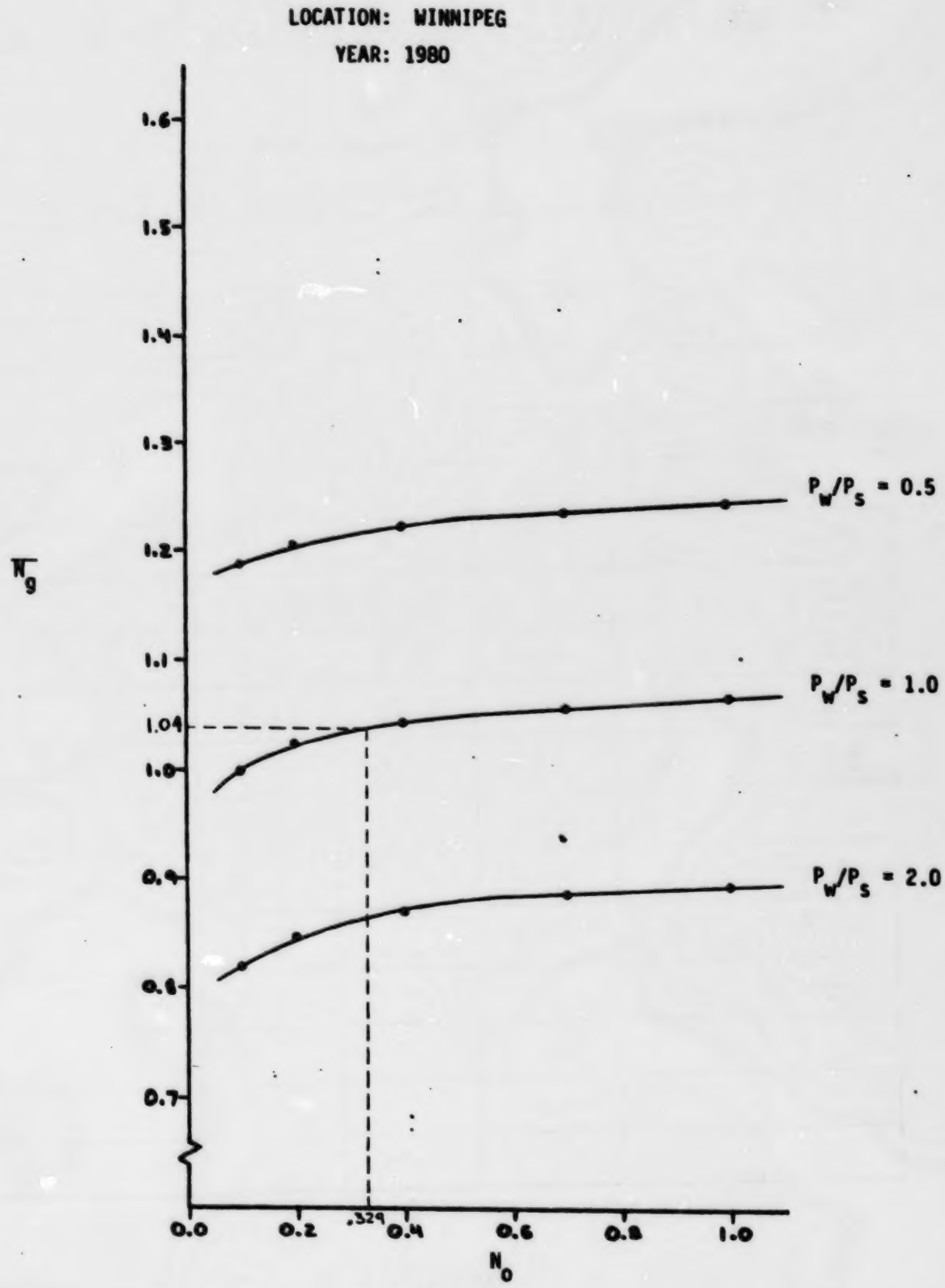


Figure B1 ANNUAL AVERAGE GRANT NUMBER VS. ORR NUMBER

TEST No 1 DATE 85/03/25 TIME 6:50

Phase Two

CONDITIONS House As Is

WEATHER Wind SSE 24 G44, Temp 4, P 100.91

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
0	0	0	0	-8.1	
8.2	.115	.115	156	2.1	
13 8	.216	.216	213	6.3	
19.0	.358	.358	274	8.5	
28.2	.610	.610	357	12.1	
35.3	.842	.842	419	16.5	
40.1	1.010	1.010	459	21.5	
32.7	.758	.758	398	16.3	
24 5	.522	.522	331	12.5	
18.0	.334	.334	265	7.4	
11.4	.170	.170	189	5.1	
0	0	0	0	-6.4	

TABLE B2.1

TEST No 2 DATE 85/03/25 TIME 7:05

Phase Two

CONDITIONS No Duct Fan, Fireplace ON

WEATHER Wind SSE 24G44, Temp 4, P 10090

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
2.5	.002	0	0	-2.0	
5.8	.068	.066	118	1.4	
7.2	.235	.233	221	2.4	
11.2	.413	.411	294	4.9	
16.1	.633	.631	363	6.4	←
22.5	.878	.876	428	6.3	←
22.7	1.001	.999	457	10.1	
17.4	.740	.738	393	8.6	
15.2	.547	.545	338	6.0	
11.8	.321	.319	259	3.1	
5.2	.152	.150	178	1.5	
2.6	.002	0	0	-2.0	

TABLE B2.2

TEST No 3 DATE 85/03/25 TIME 7:25

Phase Two

CONDITIONS No Duct Fan, Fireplace, Kitchen Fan on

WEATHER Wind SSE 24 G44, Temp 4, P 100.90

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
6.0	.003	0	0	1.5	BACKDRAFT
9.2	.150	.147	176	4.7	
15.0	.319	.316	259	6.3	
20.3	.521	.518	329	8.5	
23.0	.738	.735	392	11.5	
28.1	.962	.959	447	14.6	
25.7	.854	.851	422	14.3	
22.0	.625	.622	361	11.4	
17.1	.411	.408	292	8.0	
15.2	.225	.222	216	3.8	
12.0	.097	.094	141	3.0	
5.1	.002	0	0	1.5	←

TABLE B2.3

TEST No 4 DATE 85/03/25 TIME 7:35

Phase Two

CONDITIONS No Duct Fan, Fireplace, Dryer on

WEATHER Wind SSE 24 644, Temp 4, P 100.90

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
2.9	0	0	0	0.4	←
8.0	.100	.100	145	-0.6	←
10.2	.227	.227	218	2.1	
13.4	.394	.394	287	3.0	
17.1	.628	.628	362	4.6	
22.0	.862	.862	424	7.6	
26.3	.990	.990	455	9.8	
17.9	.745	.745	395	9.5	
9.0	.534	.534	334	9.0	
11.1	.316	.316	258	7.4	←
6.3	.185	.185	197	4.6	
3.7	0	0	0	-0.6	

TABLE B2.4

TEST No 5 DATE 85/03/25 TIME 7:45

Phase Two

CONDITIONS No Duct Fan, Fireplace, Furnace on

WEATHER Wind SSE 24644, Temp 4, P 100.90

HP (Pa)	ND (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
3.1	.002	0	0	-9.3	
6.8	.183	.181	195	-9.0	
12.1	.316	.314	257	-7.0	
15.2	.463	.461	311	-4.0	
16.9	.729	.727	390	2.0	
20.5	.962	.960	448	4.0	← Gusty
21.5	.848	.846	420	9.4	←
14.8	.624	.622	361	7.1	
13.2	.400	.398	289	6.4	
5.8	.226	.224	217	3.2	
4.2	.114	.112	154	1.6	
3.2	.001	0	0	-9.4	

TABLE B2.5

TEST No 6 DATE 85/03/25 TIME 7:55

Phase Two

CONDITIONS No Duct Fan, Fireplace, Furnace, Kitchen Fan on

WEATHER Wind SSE 24644, Temp 4, P 100.90

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
6.1	0	0	0	-8.5	
10.8	.095	.095	142	-5.1	
13.8	.202	.202	206	-2.3	
17.5	.350	.350	271	4.6	
20.4	.586	.586	350	10.4	
23.7	.817	.817	413	12.4	
26.2	.950	.950	445	14.1	
22.1	.686	.686	379	11.0	
17.3	.502	.502	324	8.5	
13.9	.295	.295	249	6.1	
8.3	.148	.148	177	4.8	
1.4	0	0	0	1.8	← STILL BACKDRAFTS

TABLE B2.6

TEST No 7 DATE 85/03/25 TIME 8:10

Phase Two

CONDITIONS No Duct Fan Fireplace, Furnace, Dryer On, Kitchen Fan On

WEATHER Wind SSE 28, Temp 4, P 100.92

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
7.5	0	0	0	-8.0	
13.2	.149	.149	177	-1.3	
16.2	.300	.300	251	5.1	
20.8	.477	.477	316	8.3	
31.0	.689	.689	380	10.1	←
32.6	.940	.940	443	6.7	←
30.5	.804	.804	410	12.6	←
23.0	.608	.608	357	1.00	
17.8	.378	.378	286	9.7	
13.6	.206	.206	208	7.8	
12.2	.094	.094	141	5.1	
7.0	0	0	0	1.3	← STILL BACKDRAFTS

TABLE B2.7

TEST No 8 DATE 85/03/25 TIME 8:30

Phase Two

CONDITIONS No Duct Fan, Kitchen Fan On

WEATHER Wind SSE 28, Temp 4, P 100.92

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
6.8	0	0	0	-1.9	
8.3	.102	.102	147	3.0	
12.2	.234	.234	222	5.6	
19.5	.398	.398	289	6.1	
23.7	.612	.612	358	7.1	
29.5	.870	.870	426	11.9	
30.0	1.009	1.009	459	14.6	
23.0	.732	.732	391	12.0	
19.0	.504	.504	325	9.2	
14.6	.315	.315	257	6.1	
10.2	.161	.161	184	4.2	
6.1	.004	.004	29	0.9	← STILL BACKDRAFT

TABLE B2.8

TEST No 9 DATE 85/03/25 TIME 8:45

Phase Two

CONDITIONS No Duct Fan, Furnace On

WEATHER Wind SSE 28, Temp 4, P 100.92

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
2.4	.002	0	0	-10.4	
6.5	.159	.156	181	-11.3	
11.0	.333	.330	263	-6.4	
19.5	.505	.502	324	-3.9	"
19.0	.773	.770	401	-1.3	"
20.7	1.009	1.006	458	5.8	
18.9	.846	.843	420	9.1	
15.9	.592	.589	351	7.3	
12.0	.406	.403	291	6.7	
7.8	.210	.207	209	4.3	
7.0	.102	.099	145	0.8	
1.2	.004	.001	15	-12.0	

TABLE B2.9

TEST No 10 DATE 85/03/25 TIME 8:50

Phase Two

CONDITIONS No Duct Fan, Furnace, Kitchen Fan On

WEATHER Wind SSE 28, Temp 4, P 100.92

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
5.2	0	0	0	-10.9	
11.9	.095	.095	142	-10.9	
15.9	.212	.212	211	-5.1	←
15.8	.370	.370	279	-3.0	←
22.5	.562	.562	343	4.8	
26.5	.835	.835	418	7.1	
30.8	.978	.978	452	11.2	
29.1	.857	.857	423	12.4	
21.1	.610	.610	357	11.3	
16.2	.404	.404	291	9.6	
11.5	.232	.232	221	7.8	
8.8	.106	.106	150	6.0	
3.9	.001	.001	15	1.5	← STILL BACKDRAFTING

TABLE B2.10

TEST No 11 DATE 85/03/25 TIME 9:00

Phase Two

CONDITIONS No Duct Fan, Furnace, Kitchen Fan, Dryer On

WEATHER Wind SSE 26 G 39, Temp 4, P100.97

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
3.2	0	0	0	-9.3	
14.2	.099	.099	145	-10.0	
18.1	.209	.209	210	-4.3	
18.6	.419	.419	296	-1.2	
23.5	.581	.581	349	6.1	
26.4	.828	.828	416	9.8	
30.4	1.019	1.019	461	13.5	
30.0	.832	.832	417	14.3	
29.4	.577	.577	348	8.3	←
17.8	.388	.388	285	9.4	
13.6	.222	.222	216	7.5	
10.5	.113	.113	154	6.0	
2.8	.003	.003	25	0.5	

TABLE B2.11

TEST No 12 DATE 85/03/25 TIME 9:10

Phase Two

CONDITIONS FIREPLACE SWITCH ON, FIREPLACE ON — NO INITIAL BACKDRAFT

WEATHER WIND SSE 26 G39, TEMP 4, P 100.97

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
1.5	0	0	0	-5.9	
11.0	.110	.110	152	-1.9	←
6.0	.182	.182	196	-0.6	
7.6	.275	.275	240	-0.9	
10.5	.418	.418	296	2.0	
12.8	.620	.620	360	5.0	
17.5	.840	.840	419	7.3	

TABLE B2.12

TEST No 13 DATE 85/03/26 TIME 9:15

Phase Two

CONDITIONS FIREPLACE SWITCH ON, FIREPLACE, KITCHEN FAN ON — NO INITIAL BACKDRAFT

WEATHER WIND SSE 26 639, TEMP 4, P 100.97

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
4.8	0	0	0	-1.4	
7.1	.107	.107	150	1.6	
13.7	.183	.183	196	2.7	
14.2	.289	.289	246	4.0	
16.8	.428	.428	300	5.1	
21.2	.630	.630	363	6.5	
26.7	.832	.832	417	9.1	

TABLE B2.13

TEST No 14 DATE 85/03/25 TIME 9:25

Phase Two

NO INITIAL BACKDRAFT

CONDITIONS FIREPLACE SWITCH ON, FIREPLACE, KITCHEN FAN, DRYER ON

WEATHER WIND SSE 26 G39, TEMP 4, P 100.97

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
5.0	.003	0	0	0.0	← JUST BACKDRAFTING
7.2	.101	.098	144	1.4	
11.1	.180	.177	193	3.5	
14.9	.310	.307	254	5.0	
18.4	.521	.518	329	6.6	
26.8	.712	.709	385	9.3	
28.5	.949	.946	444	12.3	

TABLE B2.14

TEST No 15 DATE 85/03/25 TIME 9:30

Phase Two

CONDITIONS FIRE PLACE SWITCH ON, FIREPLACE, FURNACE ON No INITIAL BACKDRAFT

WEATHER WIND SSE 26 G39, TEMP 4, P 100.97

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
1.0	.001	0	0	-9.8	
3.2	.113	.112	154	-6.9	
6.4	.198	.197	204	-5.1	
7.6	.337	.336	266	-3.6	
10.3	.481	.480	317	0.0	
11.6	.652	.651	369	4.9	
14.5	.822	.821	414	6.1	

TABLE B2.15

TEST No 16 DATE 85/03/26 TIME 6:00

Phase Two

No INITIAL BACKDRAFT

CONDITIONS FIRE PLACE SWITCH ON, FIREPLACE, FURNACE, KITCHEN FAN ON

WEATHER WIND N 30, TEMP 1, P 100.32

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
22	0	0	0	-5.8	
8.0	.105	.105	149	-7.6	←
7.2	.209	.209	210	-2.3	
14.6	.314	.314	257	-0.7	
12.3	.423	.423	298	1.4	←
15.5	.572	.572	346	7.3	
19.8	.821	.821	414	11.1	

TABLE B2.16

TEST No 18 DATE 85/03/26 TIME 6:15

Phase Two

CONDITIONS Fireplace Switch ON, Fireplace, Furnace, Kitchen Fan, No. INITIAL BACKDRAFT

WEATHER WIND N 30, TEMP 1, P 100.32 Dryer On

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
1.8	.006	0	0	-7.5	
5.2	.106	.100	145	-6.0	
9.1	.197	.191	200	-2.0	
13.5	.374	.368	278	4.4	
16.0	.572	.566	344	9.1	
19.3	.761	.755	397	12.0	
23.2	.983	.977	452	13.5	

TABLE B2.17

TEST No 19 DATE 85/03/26 TIME 6:25

Phase Two

NO INITIAL BACKDRAFT

CONDITIONS FAN SWITCH ON, KITCHEN FAN ON

WEATHER WIND N 30, TEMP 1, P 100.32

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
1.0	.006	0	0	-6.4	
12.3	.117	.111	153	3.7	
16.0	.212	.206	208	7.8	
22.8	.342	.336	266	8.2	
28.1	.526	.520	330	11.2	
33.1	.650	.644	367	18.1	
39.8	.855	.849	421	21.3	

TABLE B2.18

TEST No 20 DATE 85/03/26 TIME 6:30

Phase Two

No INITIAL BACKDRAFT

CONDITIONS FAN SWITCH ON, KITCHEN FAN, DRYER ON

WEATHER WIND N 30, TEMP 1, P 100.33

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
1.8	.011	0	0	-4.8	
11.1	.101	.090	138	5.2	
17.7	.197	.186	198	7.4	
22.9	.317	.306	253	10.9	
30.6	.496	.485	319	17.1	
35.5	.629	.618	360	19.3	
42.8	.830	.819	414	21.2	

TABLE B2.19

TEST No 21 DATE 85/03/26 TIME 6:35

Phase Two

No INITIAL BACKDRAFT

CONDITIONS FAN SWITCH ON, FURNACE, KITCHEN FAN, DRYER ON

WEATHER WIND N 30, TEMP 1, P 100.32

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
1.3	.012	0	0	-7.8	
11.2	.108	.096	142	3.4	
15.6	.222	.210	210	9.6	
21.0	.322	.310	255	11.9	
28.1	.484	.472	314	15.5	
34.5	.639	.627	362	18.9	
42.0	.865	.853	422	23.9	

TABLE B2.20

TEST No 22 DATE 85/03/26 TIME 6:40

Phase Two

No INITIAL BACKDRAFT

CONDITIONS FAN SWITCH ON, KITCHEN FAN, FURNACE ON

WEATHER WIND N 30, TEMP 1, P 100.32

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
-3	.012	0	0	-11.0	← -ve HP
11.4	.121	.109	152	-4.5	
13.0	.208	.196	203	4.9	
19.1	.336	.324	261	11.4	
26.2	.530	.518	329	16.8	←
32.9	.672	.660	372	14.6	
37.4	.890	.878	428	23.1	

TABLE B2.21

TEST No 24 DATE 85/03/26 TIME 6:50

Phase Two

No INITIAL BACK DRAFT

CONDITIONS DRYER SWITCH ON, DRYER, FURNACE ON

WEATHER WIND N 30, TEMP 1, P 100.32

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
-4	.012	0	0	-12.3	
8.0	.119	.107	150	-3.5	
12.3	.210	.198	204	2.3	
15.9	.366	.354	273	9.4	
22.2	.534	.522	331	14.1	
27.9	.670	.658	371	16.3	
32.7	.842	.830	416	20.3	

TABLE B2.22

TEST No 25 DATE 85/03/26 TIME 7:00

Phase Two

CONDITIONS FIREPLACE SWITCH ON, FIREPLACE ON WITH INITIAL BACKDRAFT

WEATHER WIND N 24, TEMP 1, P 100.38

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
14.6	.880	.865	425	6.3	
7.8	.538	.523	331	4.9	
3.1	.320	.305	253	3.4	
2.4	.166	.151	178	2.2	
-0.4	.093	.078	128	1.8	←
1.5	.058	.043	95	1.8	
1.5	.030	.015	56	-2.4	
-1.8	.015	0	0	-5.0	

TABLE B2.23

TEST No 26 DATE 85/03/26 TIME 7:05

Phase Two

CONDITIONS FIRE PLACE SWITCH ON, FIREPLACE, KITCHEN FAN ON WITH INITIAL BACKDRAFT

WEATHER WIND N 24, TEMP 1, P 100.38

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
19.2	.850	.833	417	11.8	
14.2	.596	.579	348	8.4	
12.7	.342	.325	261	4.9	
4.3	.175	.158	182	3.8	←
5.9	.109	.092	139	2.9	
2.2	.068	.051	104	2.0	
1.0	.017	0	0	0.3	← STILL BACKDRAFTS

TABLE B2.24

TEST No 28 DATE 85/03/26 TIME 7:10

Phase Two

CONDITIONS WITH INITIAL BACKDRAFT
Fireplace Switch On, Fireplace, Kitchen Fan, Dryer On

WEATHER Wind N 24, Temp 1, P 100.38

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
20.1	.811	.794	407	11.9	
16.1	.535	.518	329	7.8	
11.3	.312	.295	249	5.6	
6.2	.162	.145	175	4.1	
4.1	.088	.071	123	3.0	
1.6	.052	.035	578	1.9	
2.0	.017	0	0	0.5	- STILL BACKDRAFTING

TABLE B2.25

TEST No 29 DATE 85/03/26 TIME 7:20

Phase Two WITH INITIAL BACKDRAFT

CONDITIONS FIREPLACE SWITCH ON, FURNACE, FIREPLACE ON

WEATHER WIND N 24, TEMP 1, P 100.38

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
14.0	.838	.822	414	5.1	
12.2	.531	.515	328	3.3	
3.8	.299	.283	244	2.1	
3.2	.160	.144	174	3.0	
0.9	.088	.072	123	2.6	
0.0	.038	.022	68	-4.0	
-2.5	.016	0	0	-9.5	← -ve HP

TABLE B2.26

TEST No 31 DATE 85/03/26 TIME 7:25

Phase Two

CONDITIONS FIREPLACE SWITCH ON, FIREPLACE, FURNACE, KITCHEN FAN ON WITH INITIAL BACKDRAFT

WEATHER WIND N 24, TEMP 1, P 100.38

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
16.4	.779	.763	399	9.0	
14.3	.503	.487	319	7.3	
8.7	.322	.306	253	5.7	
4.8	.191	.175	192	4.1	
2.0	.091	.075	126	3.1	
1.6	.036	.020	65	0.9	
1.8	.016	0	0	-6.3	

TABLE B2.27

TEST No 33 DATE 85/03/26 TIME 7:30

Phase Two

CONDITIONS WITH INITIAL BACKDRAFT
Fireplace Switch On, Fireplace, Furnace, Kitchen Fan, Dryer On

WEATHER Wind N 24, Temp 1, P 100.38

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
18.0	.877	.863	425	13.1	
17.0	.577	.563	343	10.9	
11.6	.332	.318	258	6.4	
9.3	.192	.178	194	4.9	
4.1	.105	.091	139	2.8	
1.8	.034	.020	65	2.3	
0.3	.014	0	0	2.3	

* - HOME OWNER NOTED SMELL IN HOUSE THE SAME AS WHEN BACKDRAFTING INCIDENT OCCURED

TABLE B2.28

TEST No 34 DATE 85/03/26 TIME 7:50

Phase Two

CONDITIONS FAN SWITCH ON, KITCHEN FAN ON WITH INITIAL BACKDRAFT

WEATHER WIND N 24, TEMP 1, P 100.38

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
41.4	.905	.885	430	10.0	
30.4	.619	.599	354	7.4	
26.4	.350	.330	263	4.5	
13.5	.200	.180	195	3.9	
6.1	.095	.075	126	2.1	
-0.6	.040	.020	65	2.0	←
3.8	.020	0	0	-1.3	

TABLE B2.29

TEST No 35 DATE 85/03/26 TIME 8:00

Phase Two WITH INITIAL BACKDRAFT

CONDITIONS FAN SWITCH ON, KITCHEN FAN, DRYER ON

WEATHER WIND N 24, TEMP 1, P 100.37

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
39.4	.756	.740	393	11.4	
29.2	.526	.510	327	9.0	
20.0	.332	.316	258	5.0	
14.4	.160	.144	174	3.5	
7.1	.085	.069	121	2.9	
4.7	.033	.017	60	2.0	
-0.8	.016	0	0	0.0	

TABLE B2.30

TEST No 37 DATE 85/03/26 TIME 8:05

Phase Two

CONDITIONS FAN SWITCH ON, FURNACE, KITCHEN FAN ON WITH INITIAL BACKDRAFT

WEATHER WIND N 24, TEMP 1, P 100.37

HP (Pa)	NP (kPa)	CORRECTED NP (kPa_o)	Q (l/s)	FP (Pa)	COMMENTS
34.6	.748	.733	391	10.1	
25.4	.549	.534	334	7.3	
14.4	.321	.306	253	4.9	
8.9	.179	.164	186	4.1	
5.9	.087	.072	123	2.7	
2.7	.028	.013	53	-0.3	
-1.3	.015	0	0	-7.8	

TABLE B2.31

TEST No 38 DATE 85/03/26 TIME 8:10

Phase Two

WITH INITIAL BACKDRAFT

CONDITIONS FAN SWITCH ON, FURNACE, KITCHEN FAN, DRYER ON

WEATHER WIND N 24, TEMP 1, P 100.37

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
30.3	.747	.711	386	7.0	
26.8	.530	.494	322	6.3	
17.3	.358	.322	260	4.6	
10.7	.180	.144	174	2.9	
6.0	.079	.043	95	2.8	
1.2	.036	0	0	-4.5	

TABLE B2.32

TEST No 40 DATE 85/03/26 TIME 8:15

Phase Two

CONDITIONS DRYER SWITCH ON, FURNACE, DRYER ON WITH INITIAL BACKDRAFT

WEATHER WIND N 24, TEMP 1, P 100.37

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
30.2	.740	.729	390	6.8	
24.1	.528	.517	329	8.5	
15.6	.341	.330	263	5.8	
10.5	.170	.159	183	4.0	
5.8	.060	.049	102	2.1	
0.2	.024	.013	53	1.8	
-3.5	.011	0	0	-8.5	

TABLE B2.33

TEST No 41 DATE 85/03/26 TIME 8:30

Phase Two WITH INITIAL BACKDRAFT

CONDITIONS FURNACE SWITCH ON, FURNACE ON

WEATHER WIND N 24, TEMP 1, P 100.38

HP (Pa)	NP (kPa)	CORRECTED NP (kPa)	Q (l/s)	FP (Pa)	COMMENTS
0/s	.010	0	0	-13.8	
0.1	.012	.002	21	-8.1	
2.8	.192	.182	196	-5.7	
9.3	.305	.295	249	-2.6	
15.2	.497	.487	319	6.8	
21.1	.704	.694	381	12.7	
26.8	.843	.833	417	13.6	
18.2	.577	.567	344	11.3	
10.7	.412	.402	290	5.6	
5.3	.258	.248	228	4.2	
0.7	.132	.122	160	2.1	
-2.4	.034	.024	71	-8.8	
0/s	.010	0	0	-13.6	

TABLE B2.34

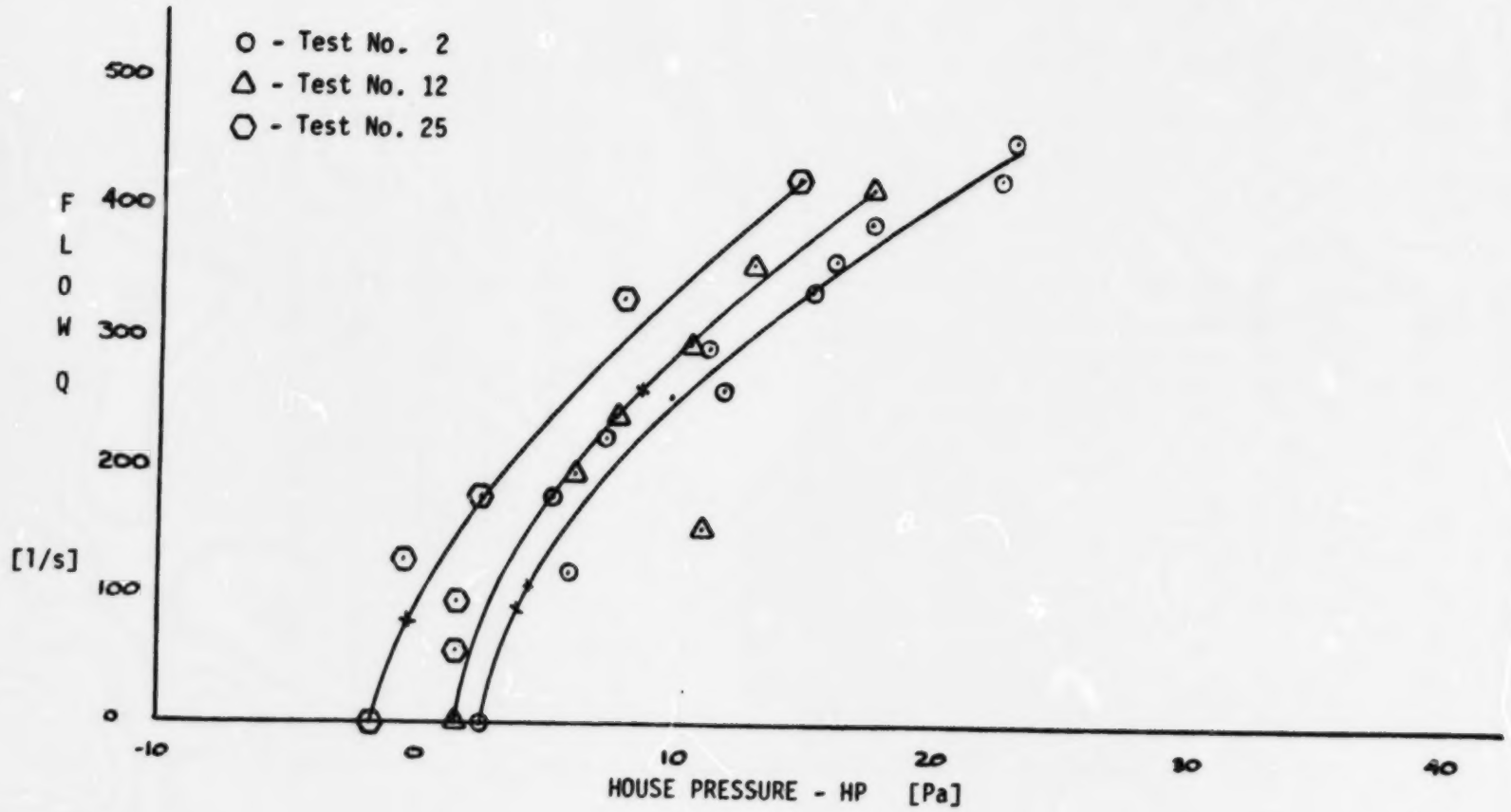

O - Test No. 2
Δ - Test No. 12
⬡ - Test No. 25
FLOW Q
[l/s]
500
400
300
200
100
0
-10
0
10
20
30
40
HOUSE PRESSURE - HP [Pa]

FIGURE B2.1

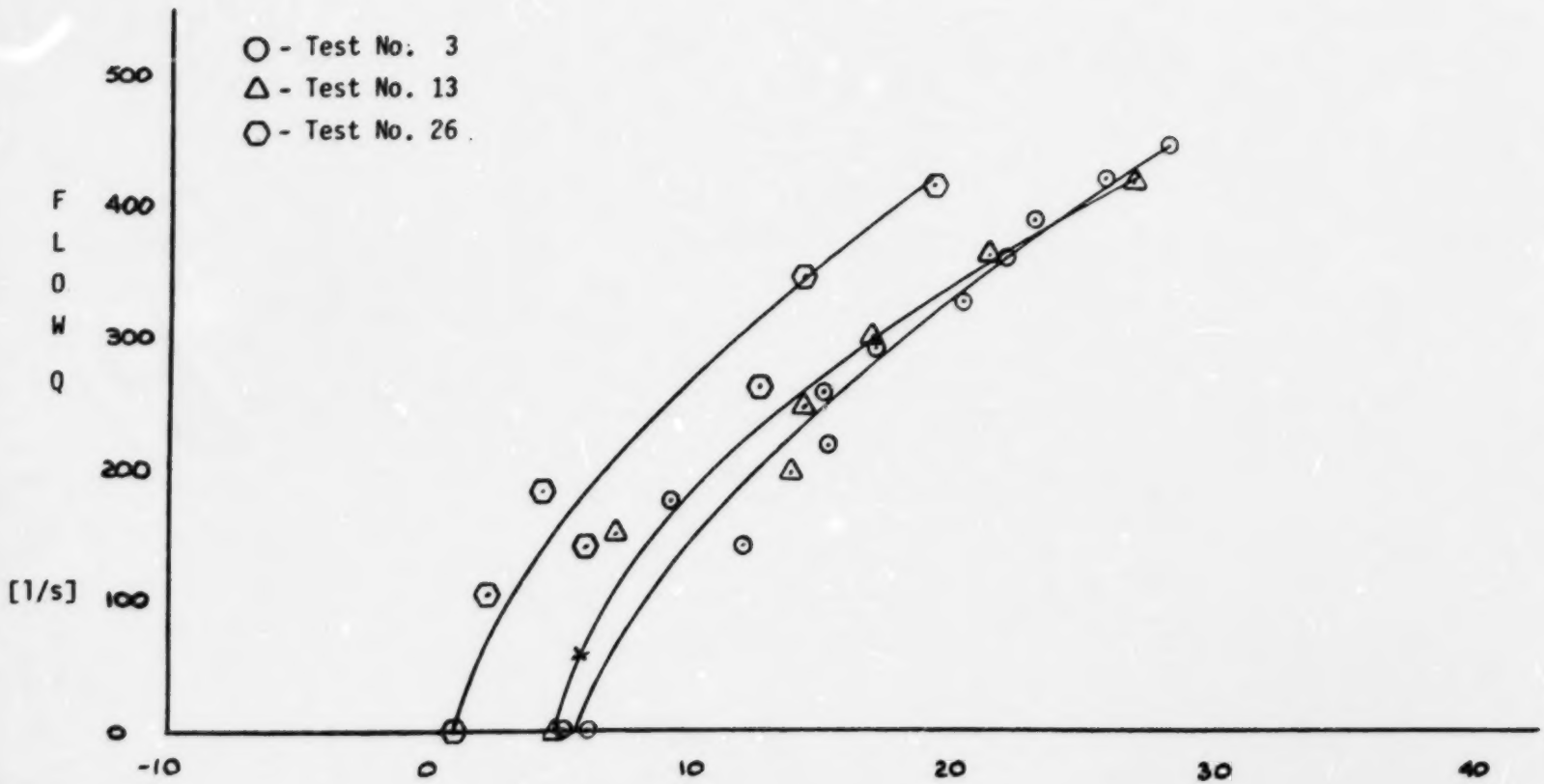

○ - Test No. 3
△ - Test No. 13
⬡ - Test No. 26
FLOW Q
[l/s]
500
400
300
200
100
0
-10
0
10
20
30
40
HOUSE PRESSURE - HP [Pa]

FIGURE B2.2

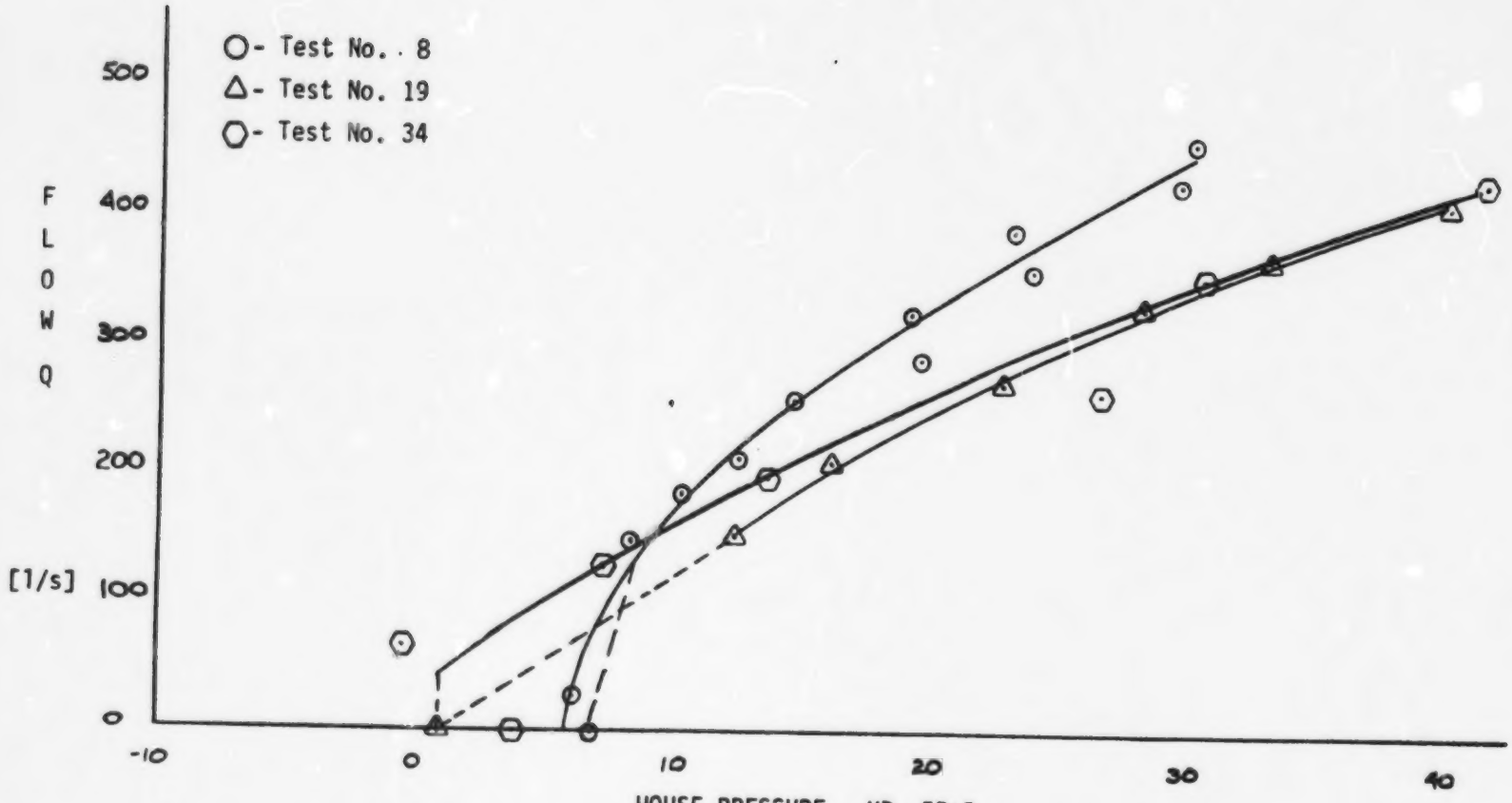

O- Test No. . 8
Δ- Test No. 19
O- Test No. 34
FLOW Q
[1/s]
500
400
300
200
100
0
-10
0
10
20
30
40
HOUSE PRESSURE - HP [Pa]

FIGURE B2.3

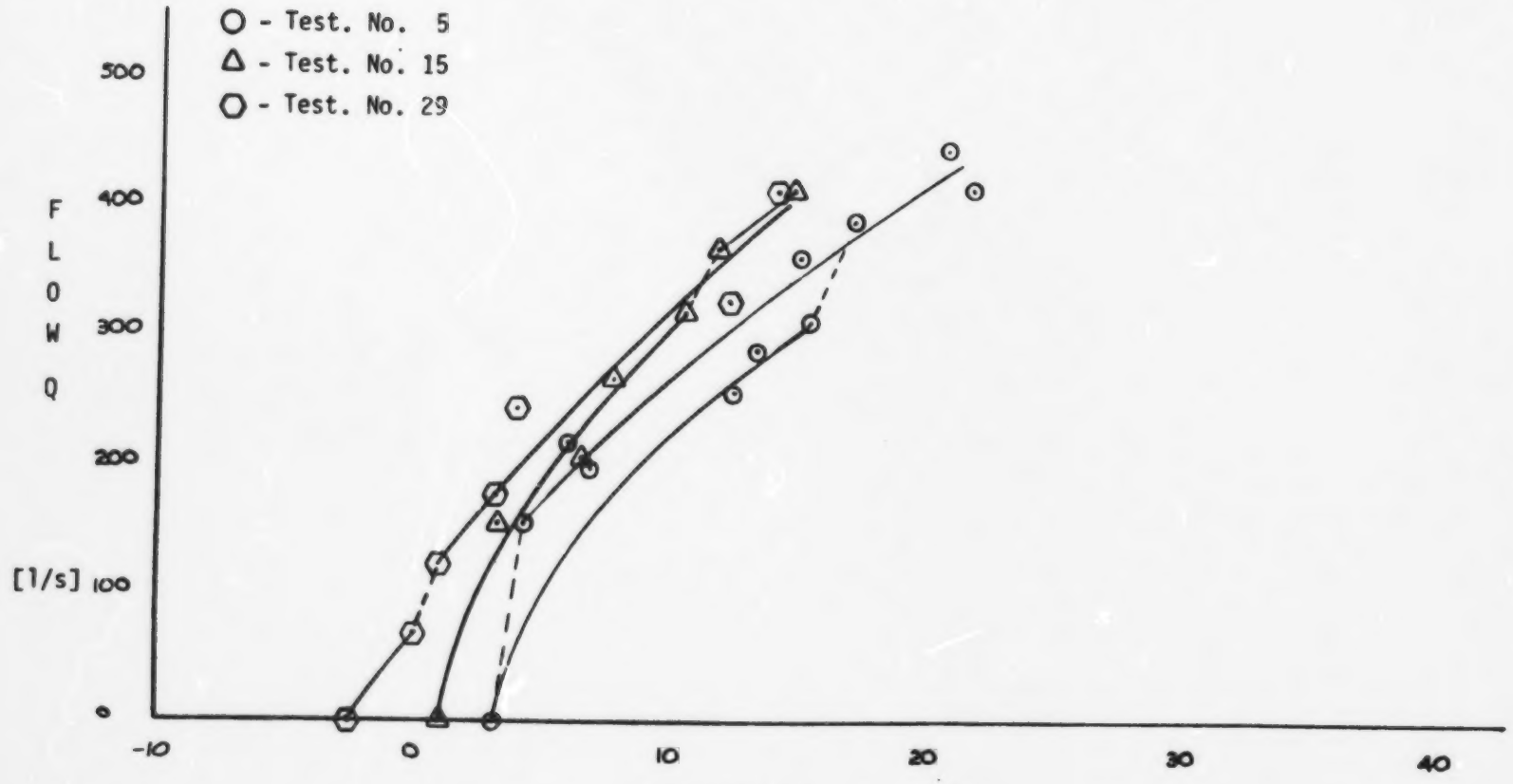

○ - Test. No. 5
△ - Test. No. 15
⬡ - Test. No. 29
FLOW Q [l/s]
500
400
300
200
100
0
-10
0
10
20
30
40
HOUSE PRESSURE - HP [Pa]

FIGURE B2.4

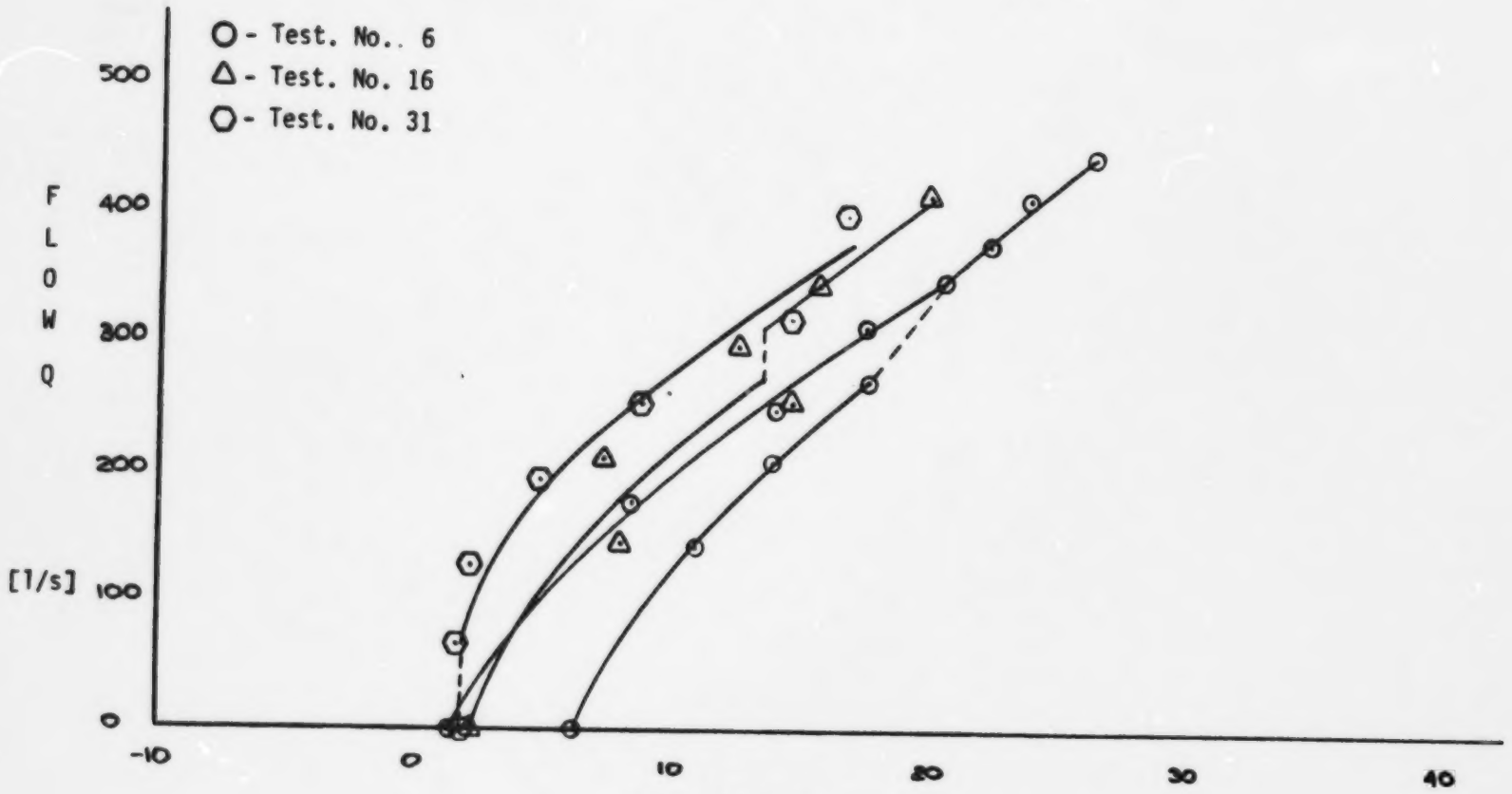

O - Test. No.. 6
Δ - Test. No. 16
O - Test. No. 31
FLOW Q
[l/s]
500
400
300
200
100
0
-10
0
10
20
30
40
HOUSE PRESSURE - HP [Pa]

FIGURE B2.5

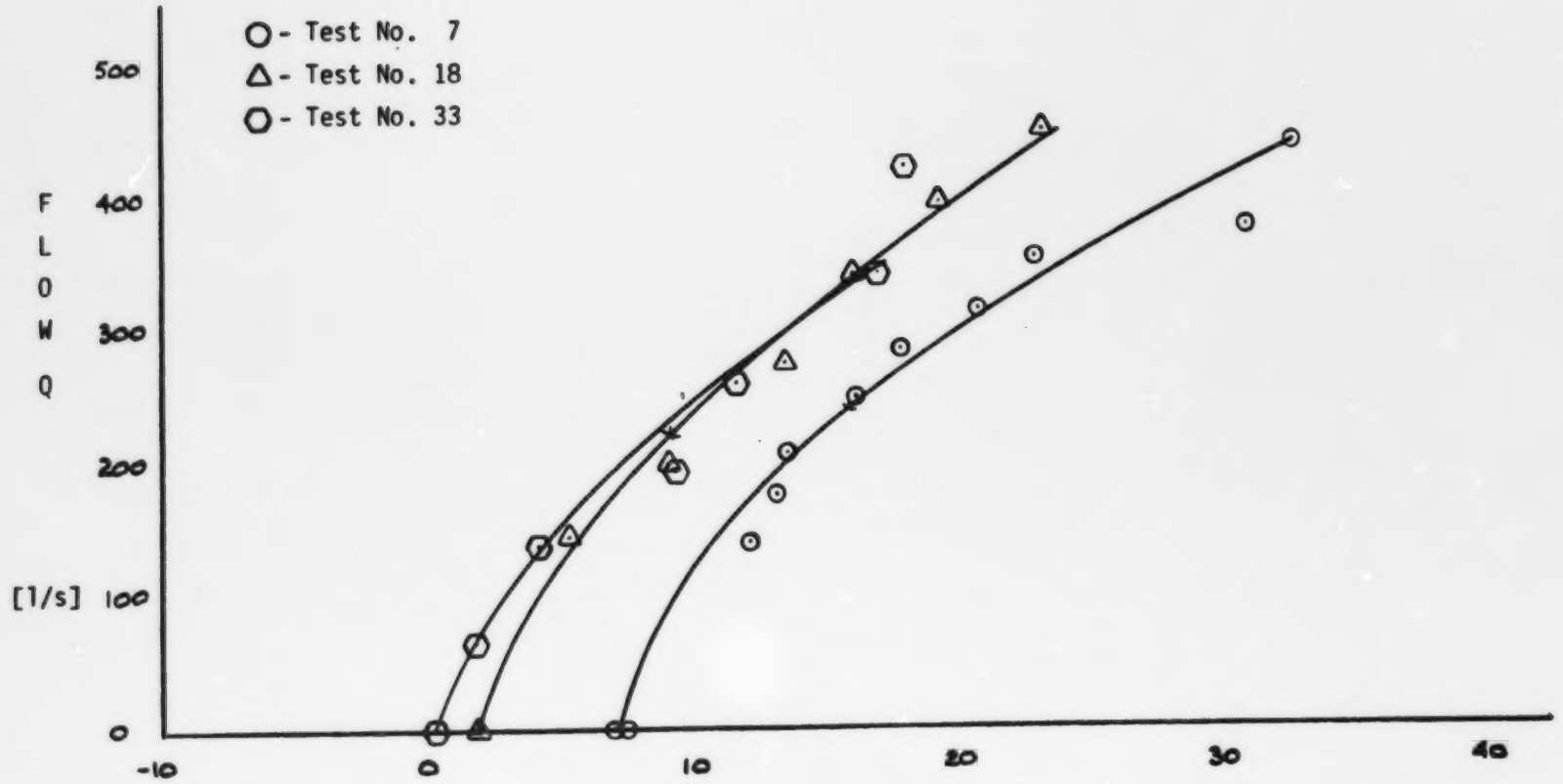

O - Test No. 7
Δ - Test No. 18
O - Test No. 33
FLOW Q
[l/s]
500
400
300
200
100
0
-10
0
10
20
30
40
HOUSE PRESSURE - HP [Pa]

FIGURE B2.6

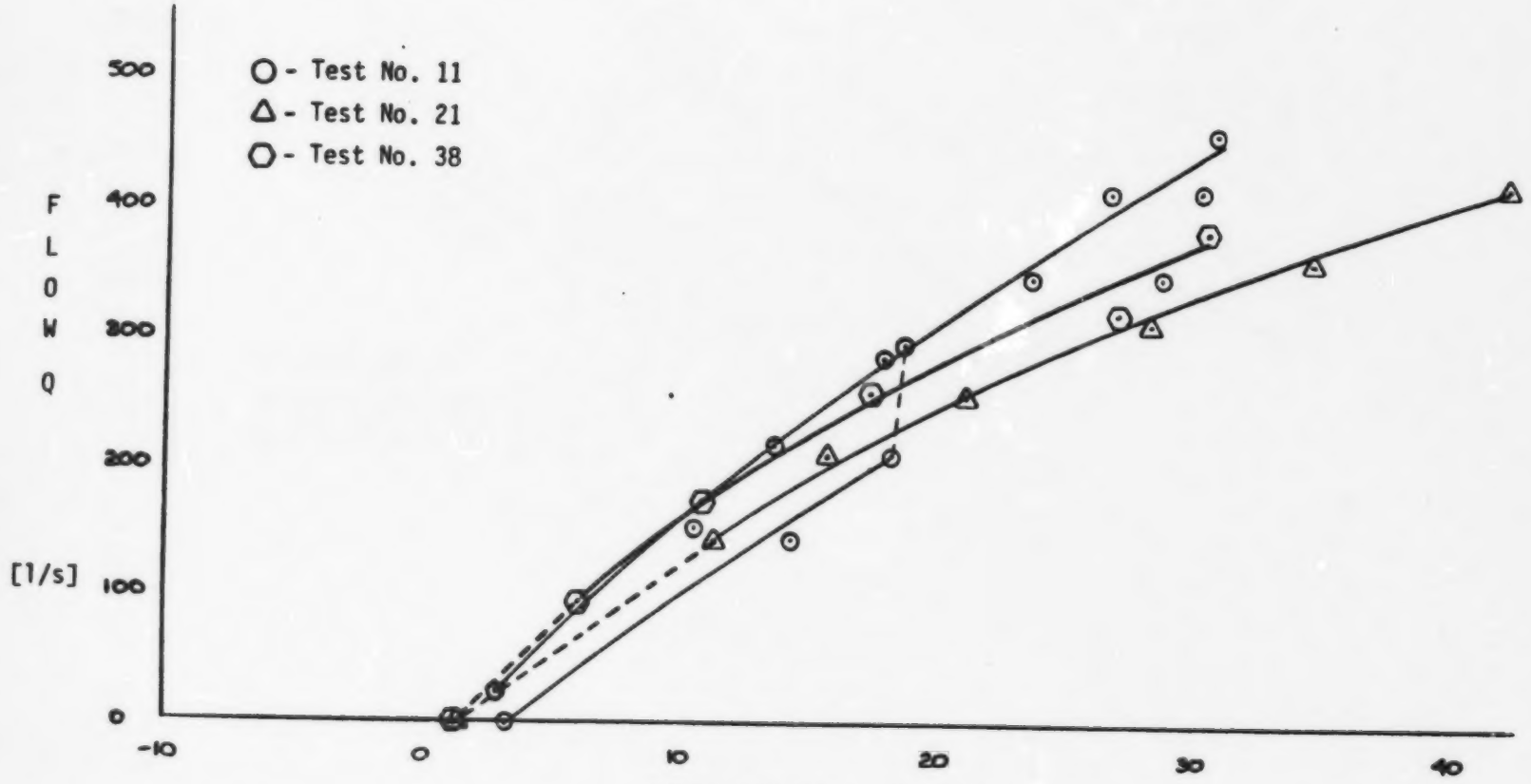

O - Test No. 11
Δ - Test No. 21
⬡ - Test No. 38
FLOW Q [l/s]
500
400
300
200
100
0
-10
0
10
20
30
40
HOUSE PRESSURE - HP [Pa]

FIGURE B2.7

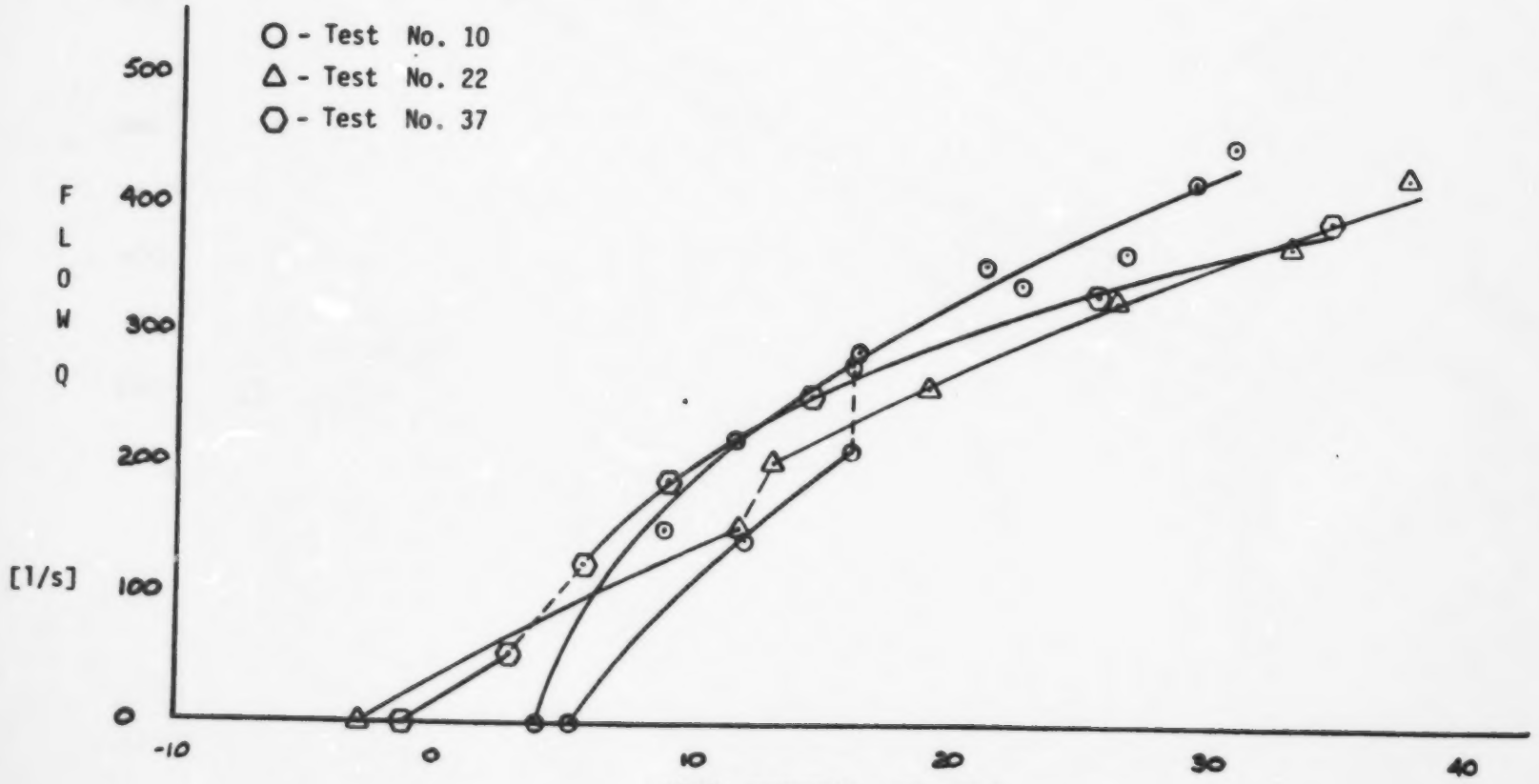

○ - Test No. 10
△ - Test No. 22
⬡ - Test No. 37
500
400
300
200
100
0
F
L
O
W
Q
[l/s]
-10
0
10
20
30
40
HOUSE PRESSURE - HP [Pa]

FIGURE B2.8

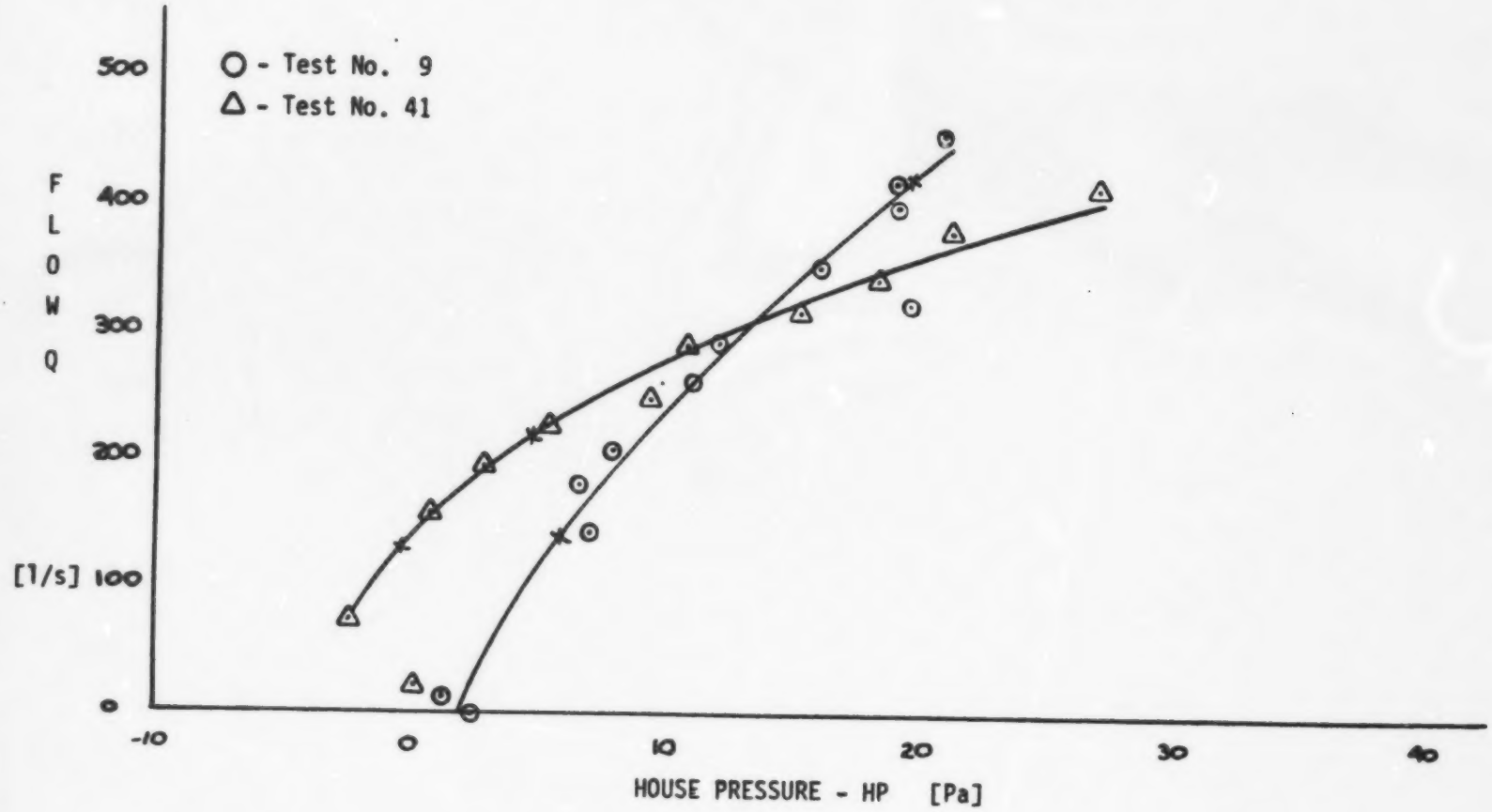

O - Test No. 9
Δ - Test No. 41
FLOW Q
[l/s]
500
400
300
200
100
0
-10
0
10
20
30
40
HOUSE PRESSURE - HP [Pa]

FIGURE B2.9

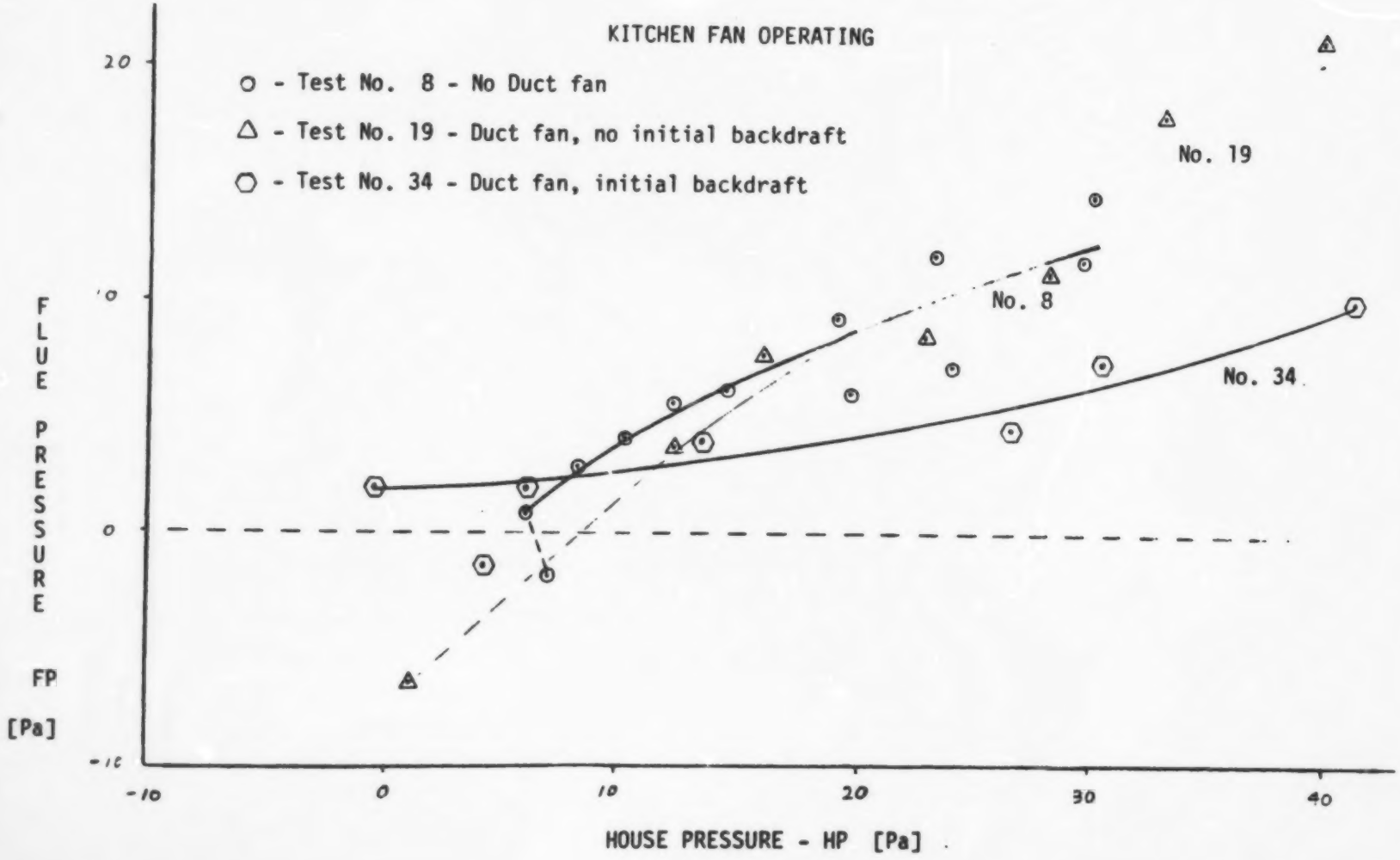

KITCHEN FAN OPERATING
○ - Test No. 8 - No Duct fan
△ - Test No. 19 - Duct fan, no initial backdraft
⬡ - Test No. 34 - Duct fan, initial backdraft
No. 19
No. 8
No. 34
FLUE PRESSURE FP [Pa]
20
10
0
-10
-10
0
10
20
30
40
HOUSE PRESSURE - HP [Pa]

FIGURE B2.10

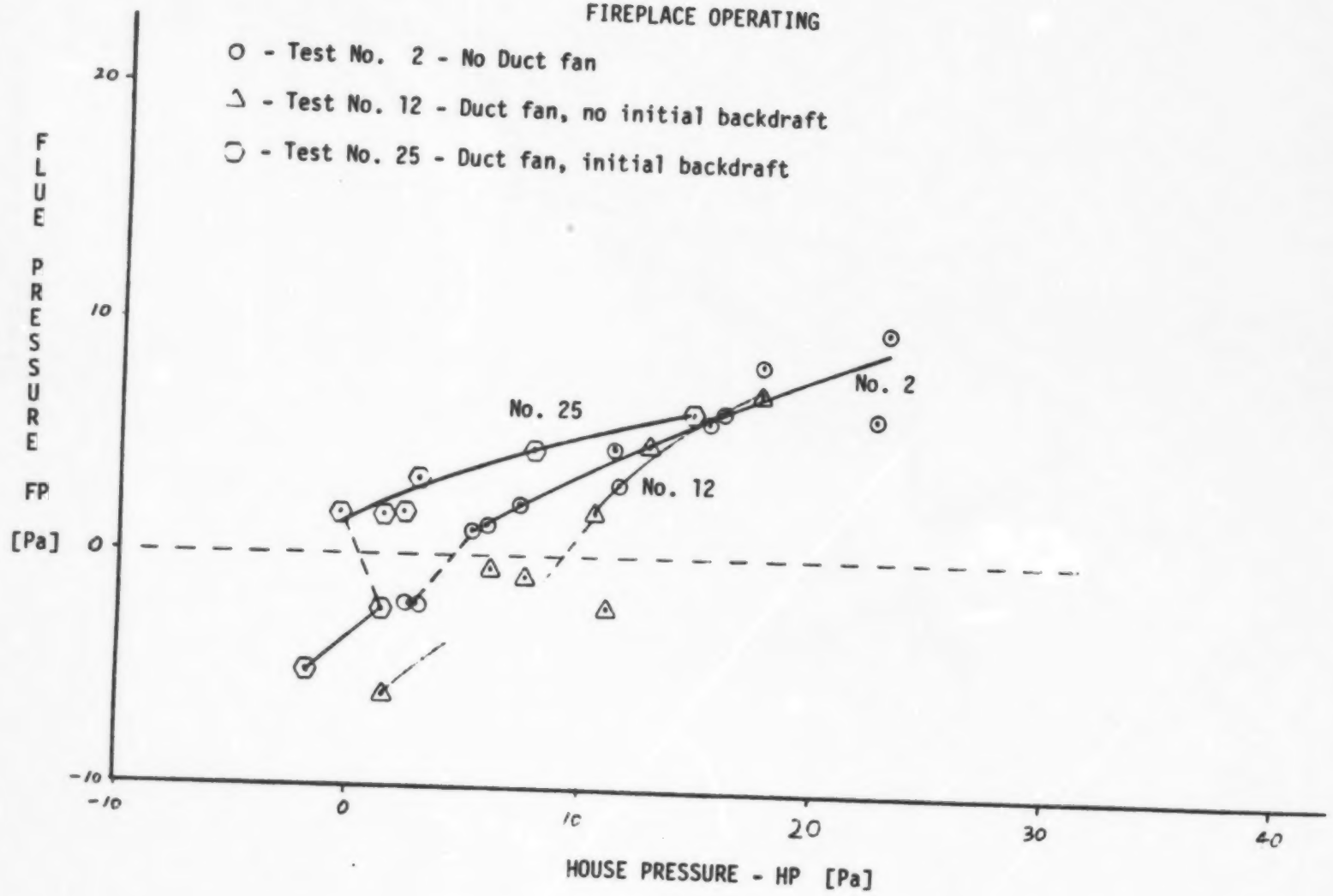

FIREPLACE OPERATING
O - Test No. 2 - No Duct fan
Δ - Test No. 12 - Duct fan, no initial backdraft
O - Test No. 25 - Duct fan, initial backdraft
FLUE PRESSURE FP [Pa]
20
10
0
-10
-10
0
10
20
30
40
No. 25
No. 2
No. 12
HOUSE PRESSURE - HP [Pa]

FIGURE B2.11

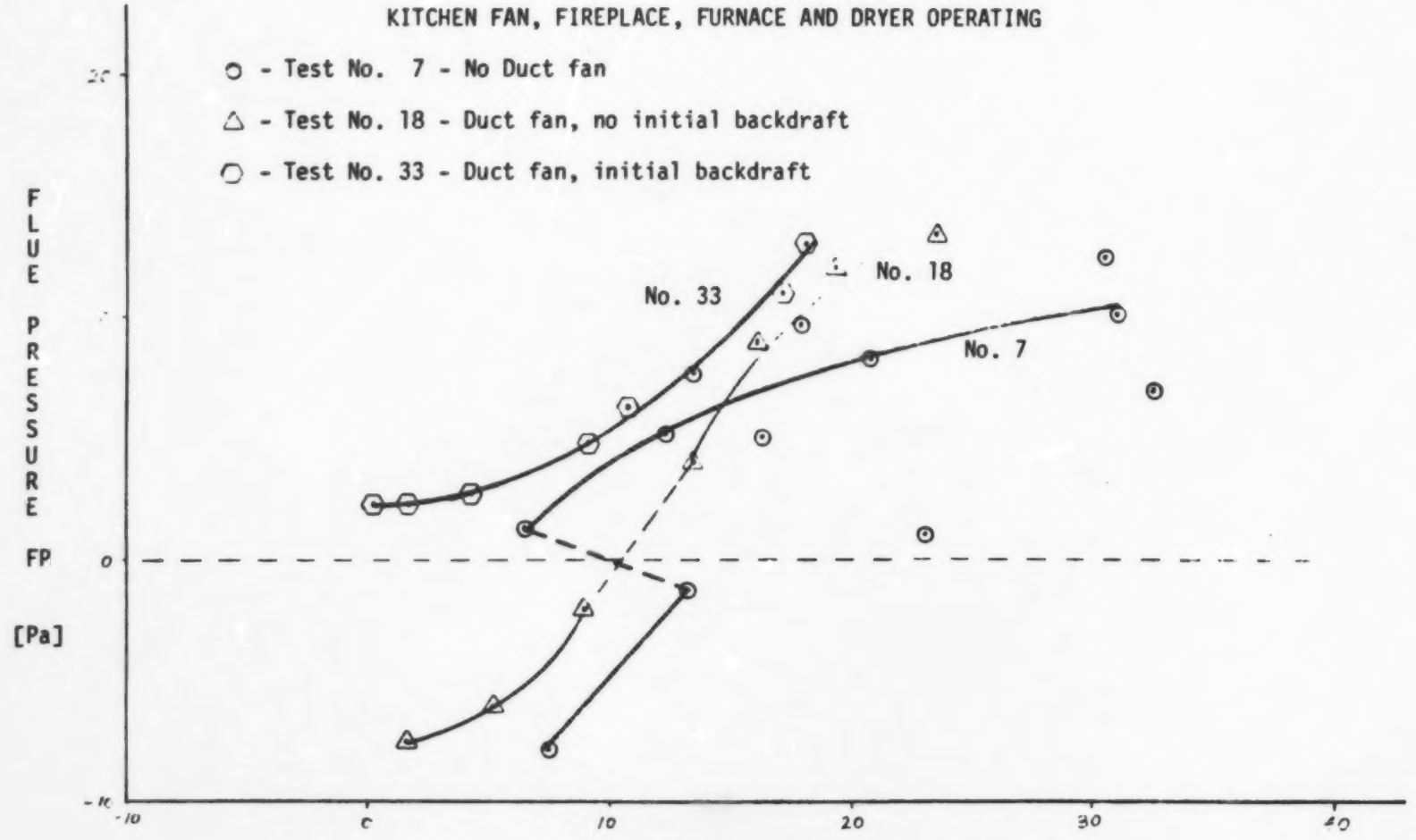

KITCHEN FAN, FIREPLACE, FURNACE AND DRYER OPERATING
○ - Test No. 7 - No Duct fan
△ - Test No. 18 - Duct fan, no initial backdraft
⬡ - Test No. 33 - Duct fan, initial backdraft
No. 33
No. 18
No. 7
FLUE PRESSURE
FP
[Pa]
0
-10
0
10
20
30
40
HOUSE PRESSURE - HP [Pa]

FIGURE B2.12

FURNACE OPERATING

○ - Test No. 9 - No Duct fan

△ - Test No. 41 - Duct fan

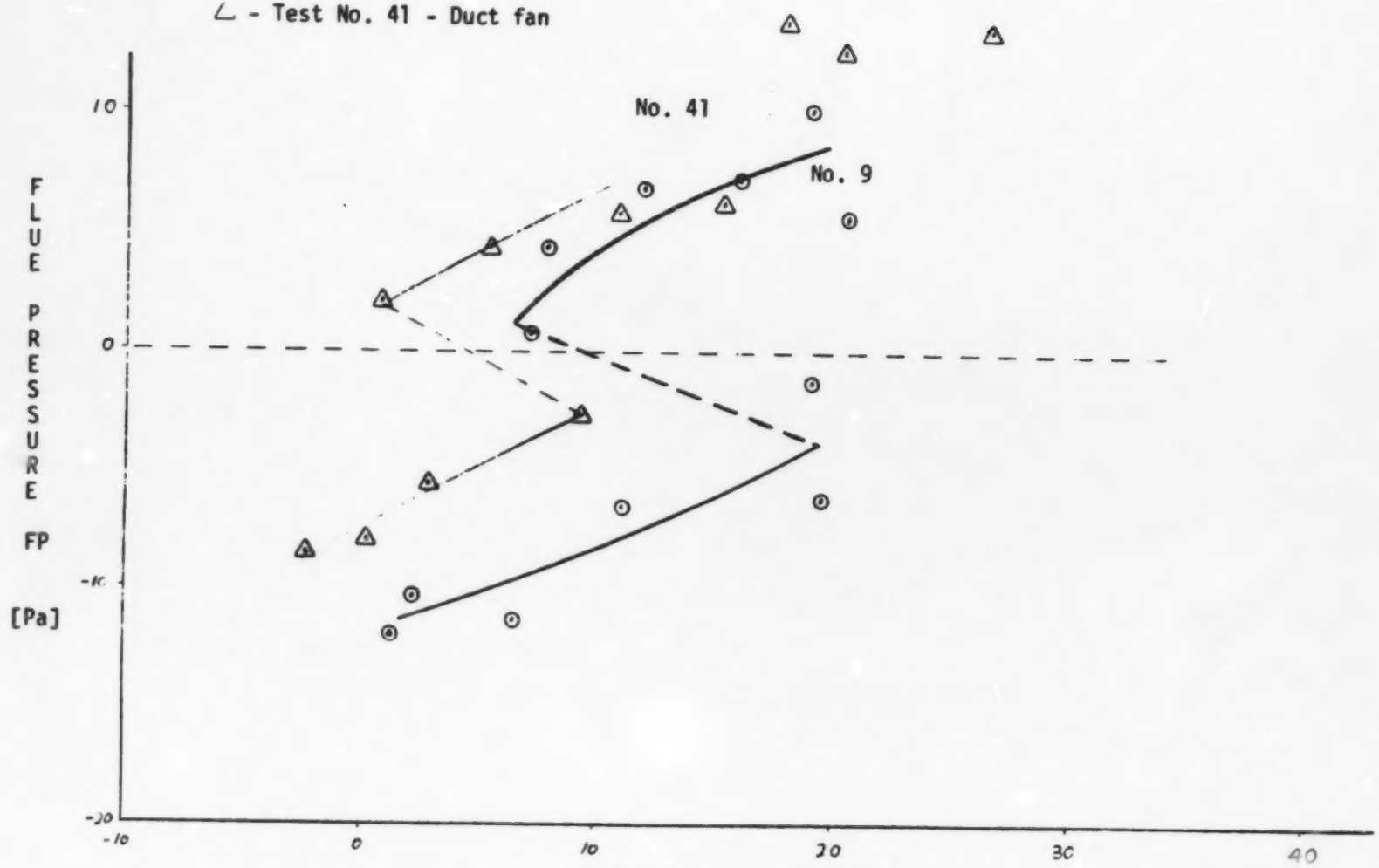


FIGURE B2.13

APPENDIX C

DUCT HEATER/FAN UNIT DESCRIPTION

Duct Heater Assembly

Figure 1.0 shows a schematic diagram of the duct heater assembly and Figure 2.0 shows the wiring diagram. Table 1.0 gives a vendor and parts list. Simply, it consists of a proportionally controlled duct heater and an axial flow fan, wih a thermistor to sense the temperature of the heated air. Pictures of duct heater are shown in Figure 3.0.

Duct Heater

The first step when assembling the duct heater is the mounting of internal components. "TEK" screws are used to mount the high limits, the terminal block, transformer and ground lug. To mount the control board #6 x 1" screws are used. The heat sink and triac are mounted to the spacer plate with two #6 x 5/8" screws. The urethane grommet is placed in the 1/2" hole through the back plate and spacer plate. The elements are mounted with "TEK" screws onto the spacer plate. The prototype provided has the enclosure fastened to the control box by means of #10 machine screws, however, the drawing has been since changed to allow the use ot #8 "taptite" screws. The adapter plates used are attached to the enclosure by means of "TEK" screws fastened. The cover is attached with #8 "taptites". Another urethane grommet is used for the manual reset hole.

The duct heater is wired using 14 gage GTF in all large current carrying wires. (See wiring diagram for terminations.) The 120V supply wires are used to supply the power to the fan. In this way the power to the fan cannot be cut off without cutting the power to the heater. The transformer used in the prototype is oversized (happened to be available). A 20VA transformer will work without a problem.

The thermistor is mounted in a copper tube. This tube does not need to be copper, a cheaper model can be used. The probe was designed to mount onto the duct by means of a strain relief. The thermistor is soldered to the leads and insulated with heat shrink then inserted into the tube and potted with silicone. The thermistor is left exposed at the end of the probe. The probe is inserted in the duct approximately 12" downstream of the heater.

Fan

The fan is a Dayton model 4C720 axial flow fan. It runs at 3400 RPM, 115 volts, 29 watts and blows 240 cfm of air. It is mounted in the duct upstream of the duct heater and runs only at the same time the heater does. Because the supply duct dumps air into the cold air plenum, upstream of the furnace fan, the duct fan should help reduce the load on the furnace fan.

The whole unit cost about $400. Installation involved one day of electrician's time wiring the system and controls and one day of an engineer's time for the installation of unit and associated ductwork.

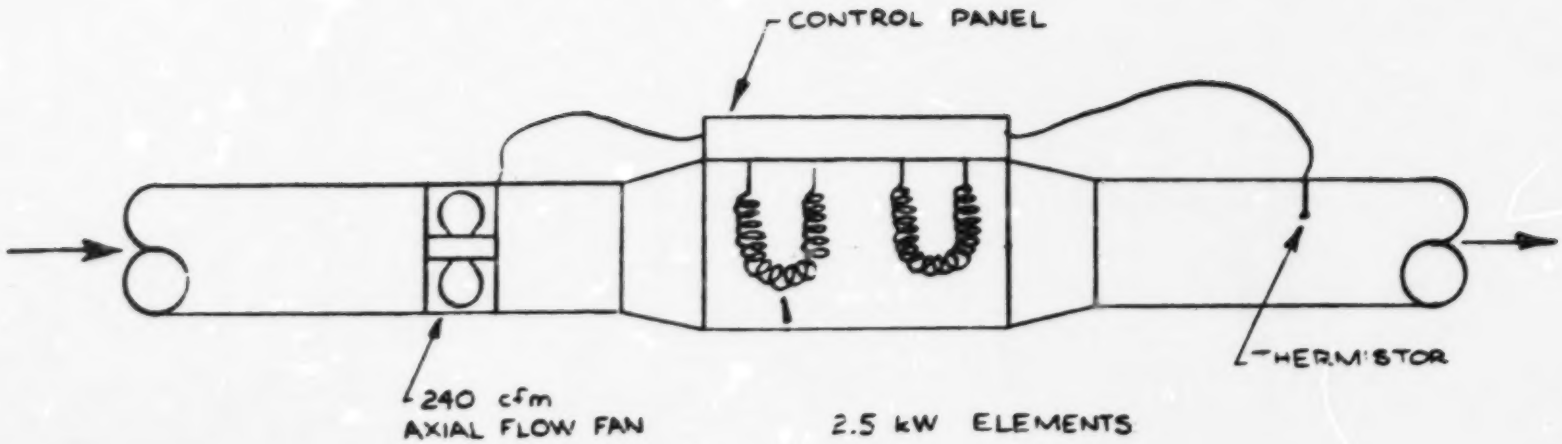


FIGURE C1

DUCT HEATER/FAN ASSEMBLY

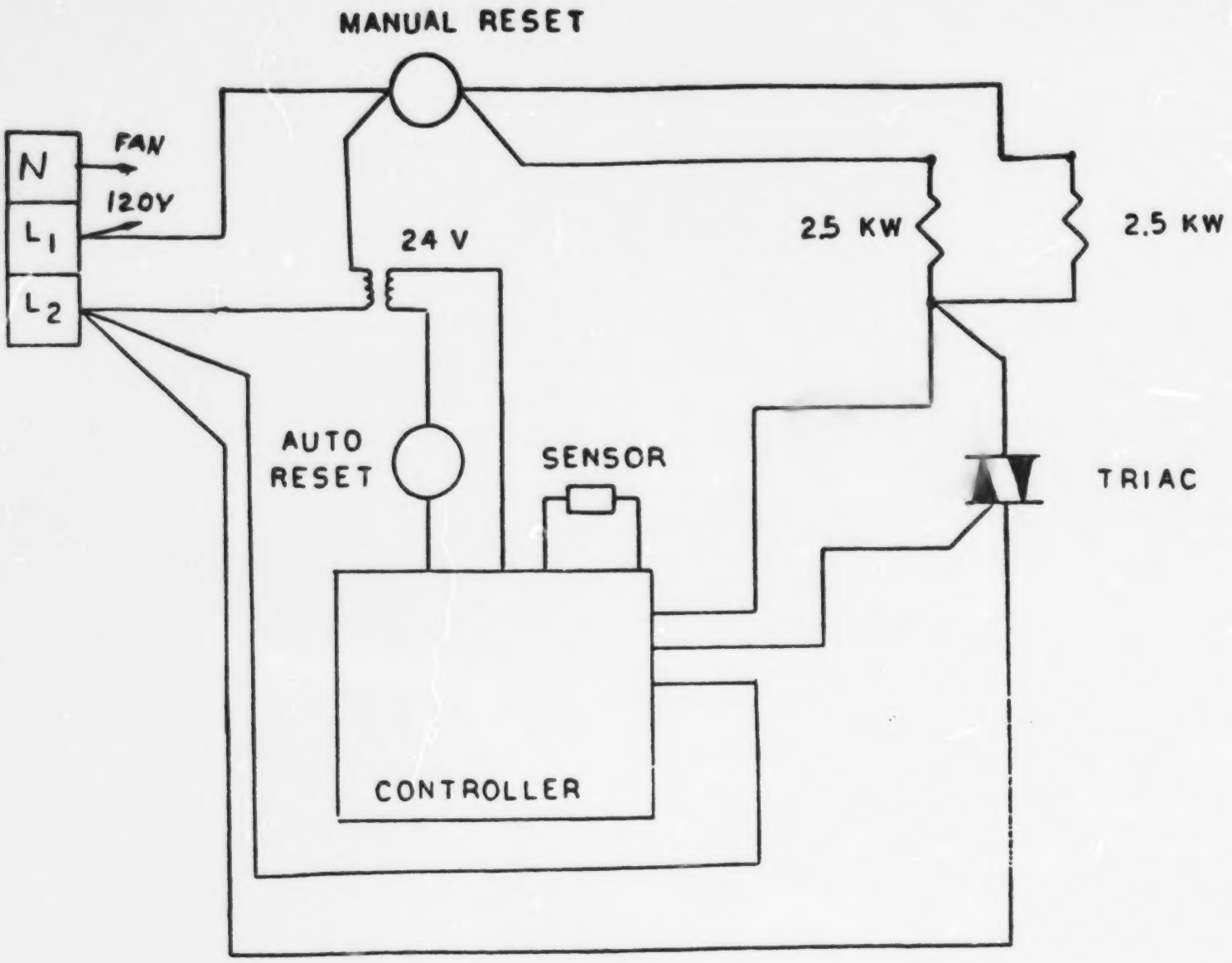
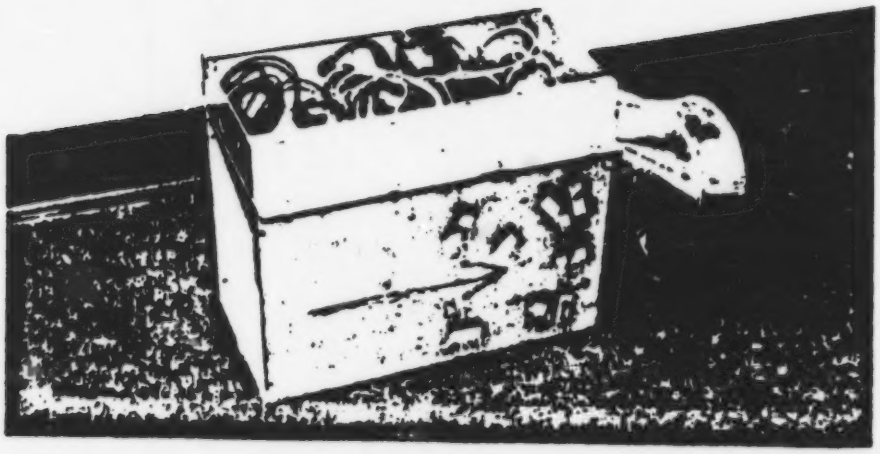
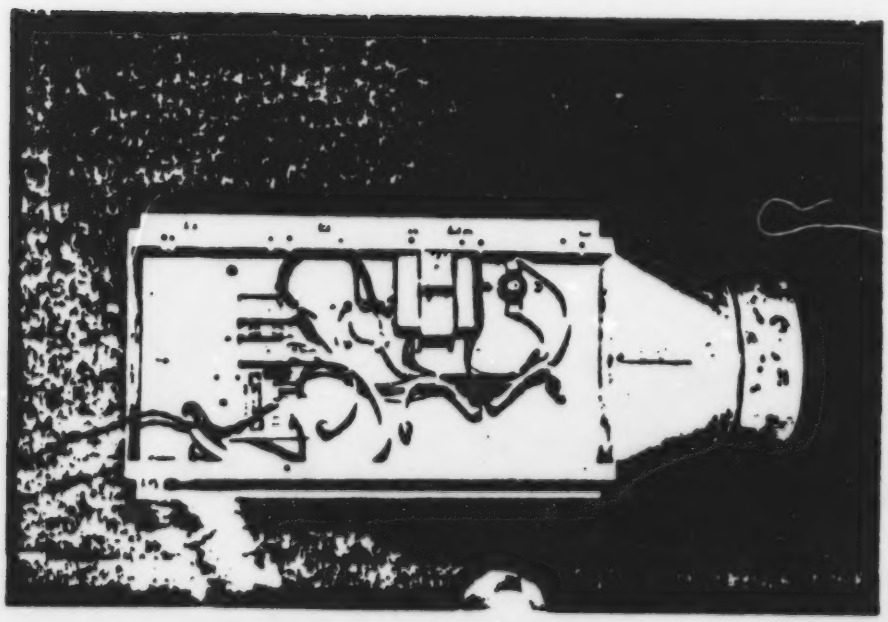


FIGURE C2

WIRING DIAGRAM

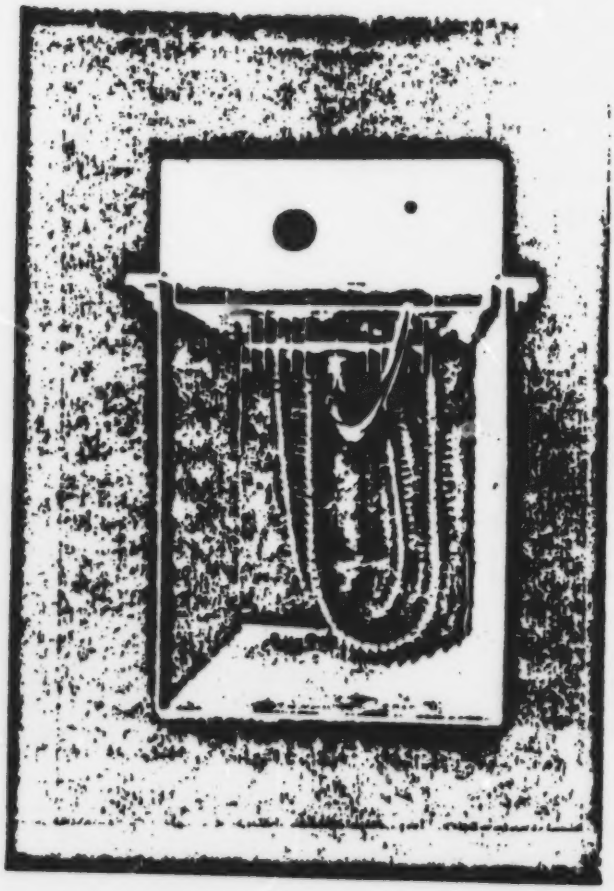


DUCT HEATER - SIDE VIEW

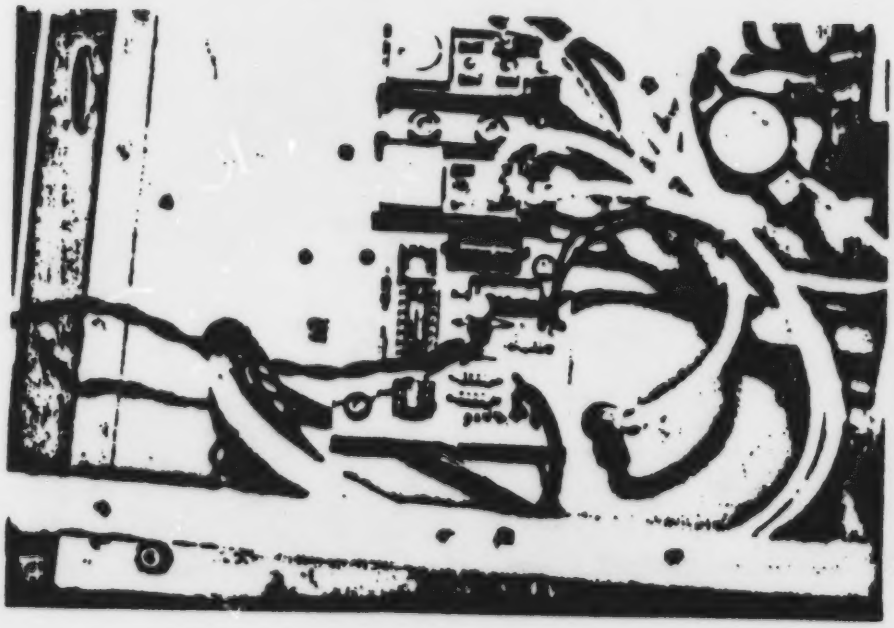


DUCT HEATER - TOP VIEW

FIGURE C3

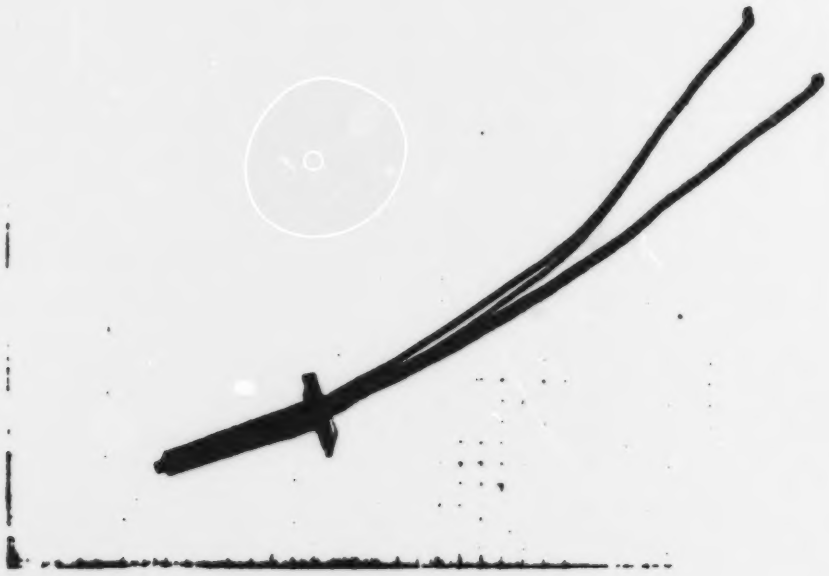


DUCT HEATER - END VIEW



CONTROI CIRCUITRY

FIGURE C3 Cont'd...



THERMISTOR

FIGURE C3 Cont'd...

TABLE C1

Duct Heater
Vendor And Parts List

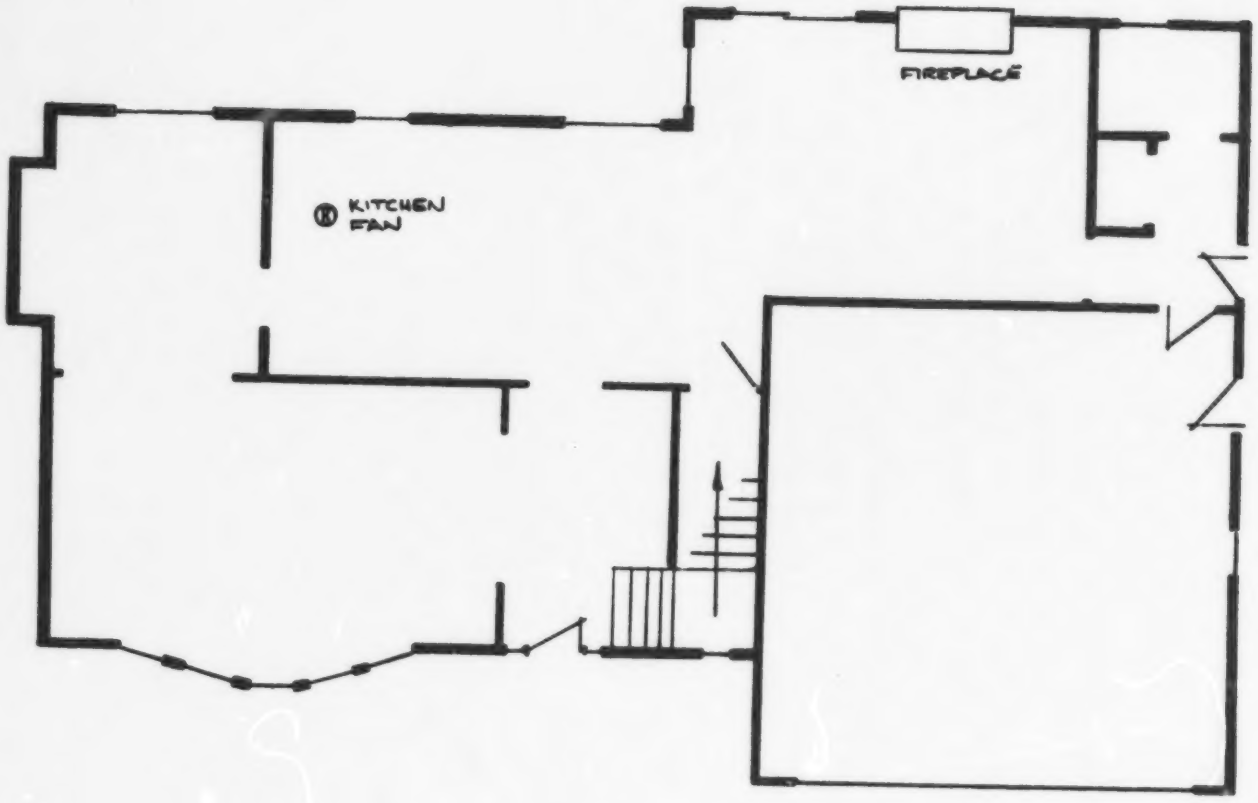
DESCRIPTION	VENDOR	PART NO.	QTY USED	UNIT PRICE	TOTAL PRICE
Manual Reset High Limit	Therm-O-Disc	60T14 L160	1	$ 2.50/ea	$ 2.50
Auto Reset High Limit	(Therm-O-Disc) Texas Instruments	Alternate 20601L-113 (L120-4)	1	2.50/ea	2.50
240V-24V Transformer	Frost	FTC4024-3	1	6.00/ea	6.00
2500W-24V Tubefinned Element	Lion Ind.	10068-0101	2	7.00/ea	14.00
Board, THermister, Triac	Lion Ind.	10281 c/w Triac/Thermistor	1 Set	37.00/ea	37.00
Urethane Grommet	Lion Ind.	10091	2	.30/ea	.60
Terminalized Heyco Bushings	Cords Canada	#4471	1	19.28/100	19.28
Terminal block 3 Pole	Westburne Amesco	Buchannan Block #5125	1	2.62/ea	2.62
Ground Lug	Lion Ind.	10092	1	.60/ea	.60
Heat Sink	Zentronics	Wakefield Engineering #1327	1	3.00/ea	3.00
Sheet Metal	Spectrum Mfg.	Submit Drawings	1 Set	25.00/set	25.00
Fastenrs (Assorted)	Anchor construction	Various Product		.75	

APPENDIX D

HOUSE DESCRIPTION

The house tested was a two storey house with an attached garage built in 1972. It has a floor area of 262 m^2, including the basement and a heated volume of 640 m^3. Both the furnace and hot water heater are gas fired. There is a commong flue for the furnace and hot water heater. The height of this flue is 5.5 meters. The fireplace is a standard open fireplace with no glass doors and no outside air supply.

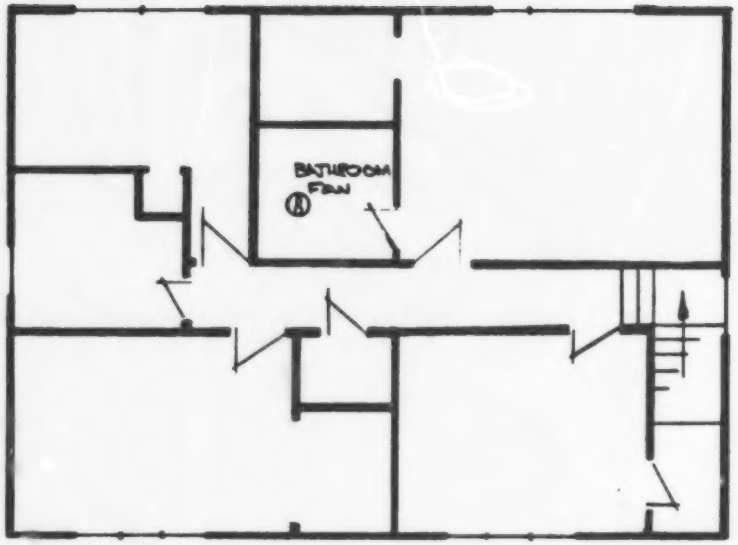
Figure D1 shows the main floor plan; Figure D2 shows the second floor plan; and Figure D3 shows the basement plan.



MAIN FLOOR

$\frac{1}{8}$" = 1'-0"

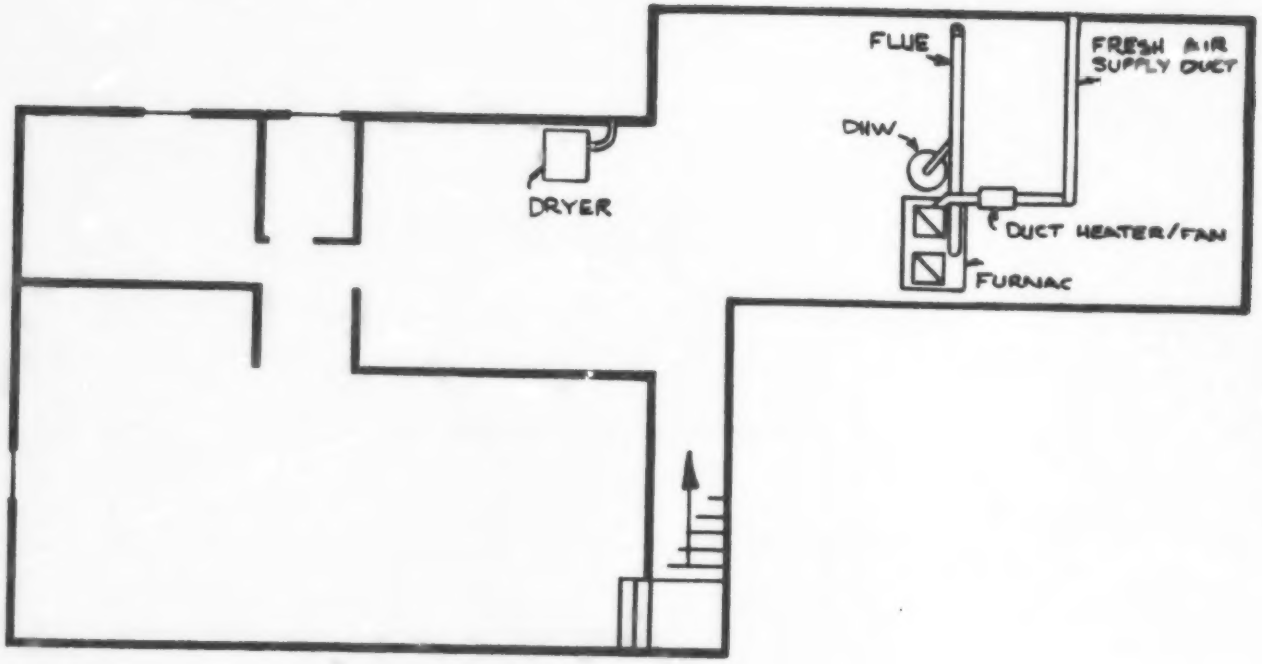
FIGURE D1



SECOND FLOOR

$\frac{1}{8}" = 1'-0"$

FIGURE D2



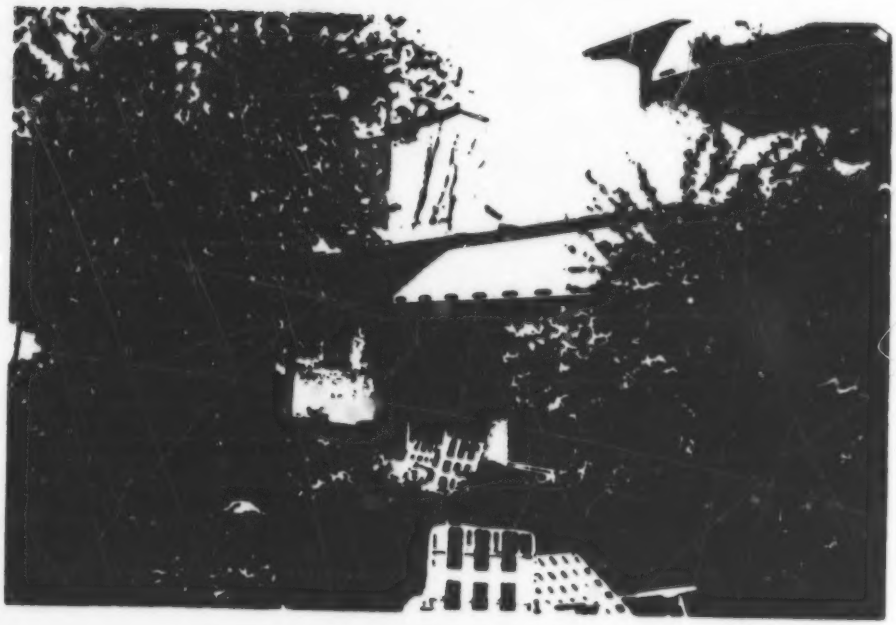
BASEMENT

$\frac{1}{8}$" = 1'-0"

FIGURE D3

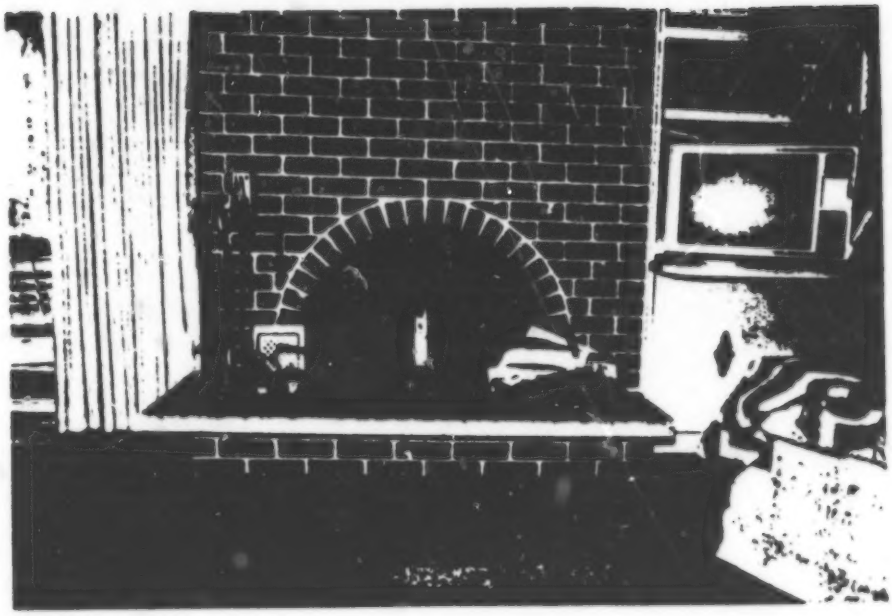
HOUSE EXTERIOR - FRONT

FIGURE D4



HOUSE EXTERIOR - REAR

FIGURE D5

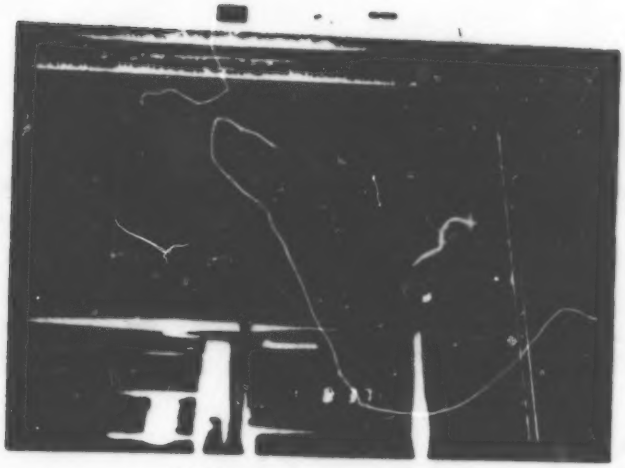


FIREPLACE

AIR CONDITIONING UNIT AND
FRESH AIR INLET
FOR HOUSE

FIGURE D6

BATHROOM EXHAUST FAN



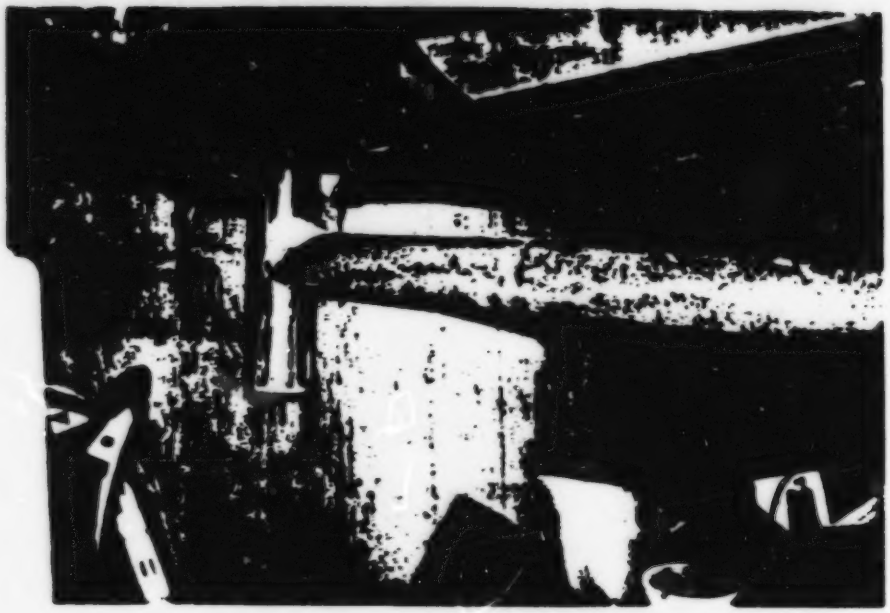
KITCHEN EXHAUST FAN

FIGURE D7

FURNACE

HOT WATER HEATER

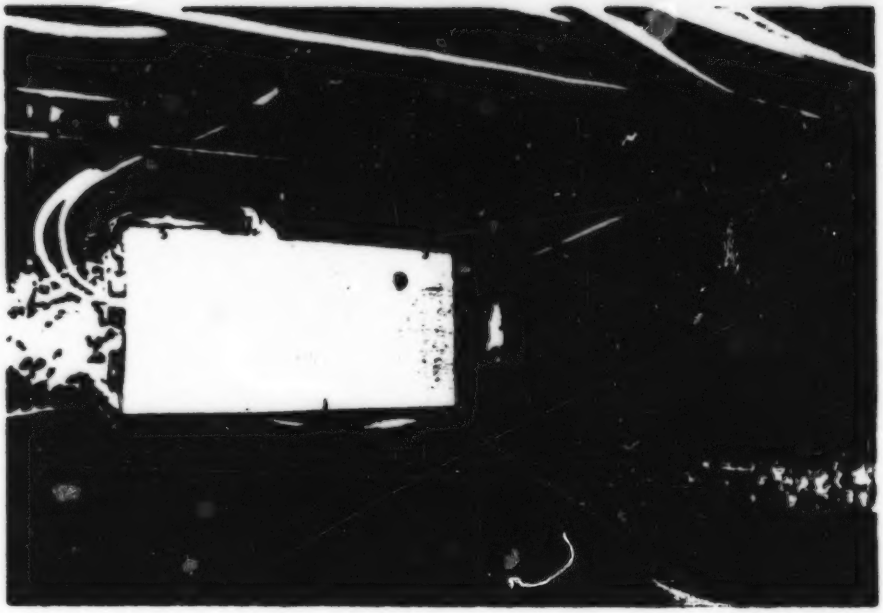
FIGURE D8



FURNACE FLUE

DUCT HEATER/FAN UNIT CONTROL
PANEL

FIGURE D9



DUCT HEATER/FAN UNIT

FIGURE D10